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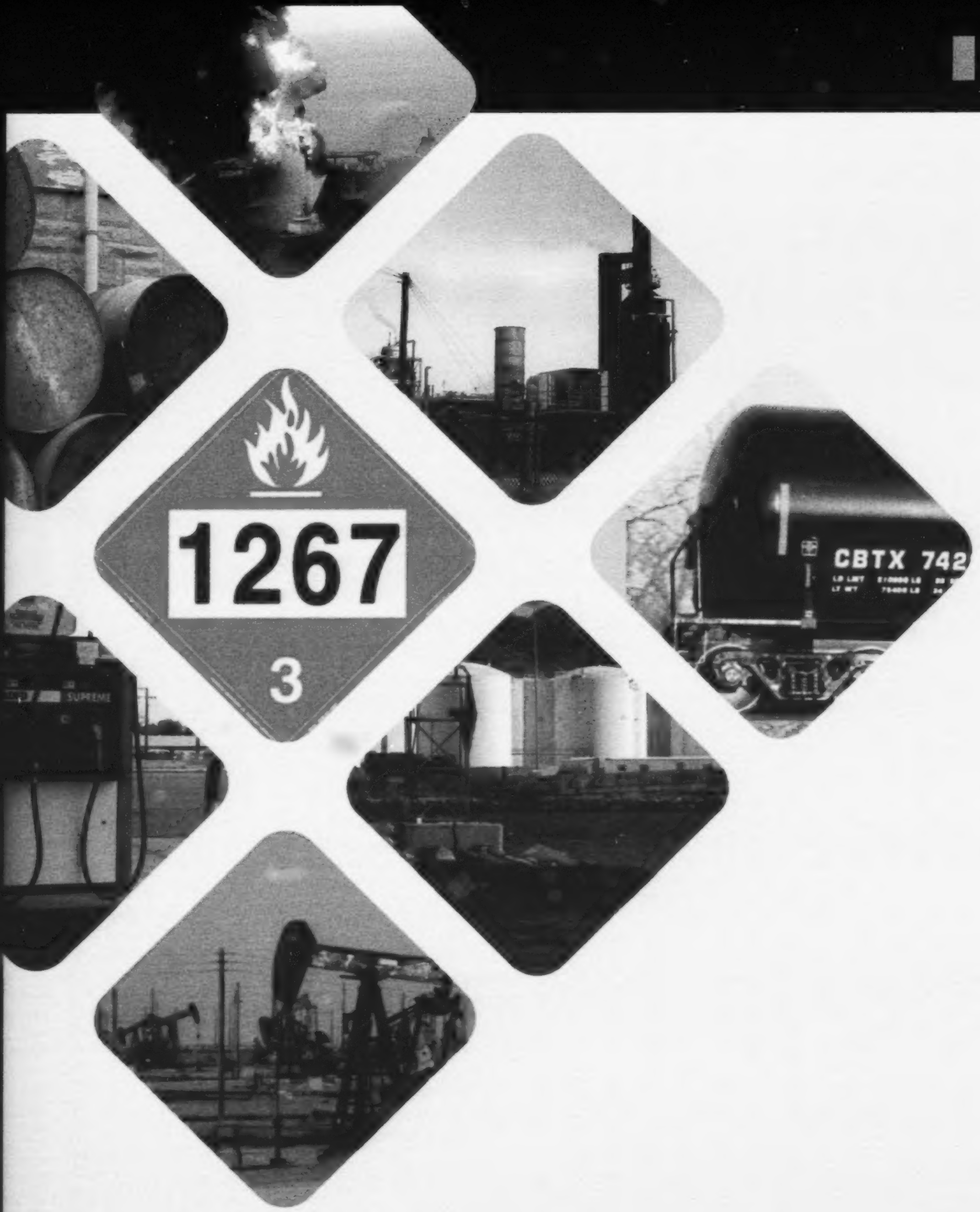

GUIDANCE FOR THE ENVIRONMENTAL PUBLIC HEALTH MANAGEMENT OF CRUDE OIL INCIDENTS

A Guide Intended for Public Health and Emergency Management Practitioners

Chemical Emergency Preparedness and Response Unit
Health Canada

August 2018

Canada

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ABBREVIATIONS AND ACRONYMS

AEGL	Acute exposure guideline levels
AFPM	American Fuel & Petrochemical Manufacturers
API	American Petroleum Institute
ARLIS	Alaska Resources Library and Information Services
ASM	American Society of Microbiology
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BCERMS	British Columbia Emergency Management System
BTEX	Benzene, toluene, ethylbenzene, xylene
CAMEO	Computer-Aided Management of Emergency Operations (CAMEO) Chemicals database and prediction tool, U.S. National Oceanic and Atmospheric Administration
CANUTEC	Canadian Transport Emergency Centre
CAPP	Canadian Association of Petroleum Producers
CAS	Chemical Abstracts Service
CAS RN	Chemical Abstracts Service Registry Number
CCG	Canadian Coast Guard
CCOHS	Canadian Centre for Occupational Health and safety
CDC	U.S. Centers for Disease Control and Prevention
CERC	Crisis and emergency risk communication
CFR	U.S. Code of Federal Regulations
CG	Canada Gazette
CHEMM	Chemical Hazards Emergency Medical Management System
CMC	Canadian Meteorological Centre
CPR	Canadian Pacific Railway
DHHS	U.S. Department of Health and Human Services
DHS	U.S. Department of Homeland Security
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DWH	Deepwater Horizon

EI	Enbridge, Inc.
EIA	U.S. Energy Information Administration
EMBC	Emergency Management British Columbia
EMS	Emergency medical services
EPA	U.S. Environmental Protection Agency
ERG	Emergency Response Guidebook
ERPG	Emergency Response Planning Guidelines
FEMA	U.S. Federal Emergency Management Agency
GC	Government of Canada
GHS	United Nations Globally Harmonized System of Classification and Labeling of Chemicals
GPAC	Transportation of Dangerous Goods General Policy Advisory Council
HazMat	Hazardous materials (or dangerous goods)
HC	Health Canada
HMG	Her Majesty's Government
HPV	High production volume
HSDB	Hazardous Substance Data Bank, U.S. National Institute of Medicine
HVAC	Heating, ventilating, and air conditioning
IARC	International Agency for Research on Cancer
ICS	Incident Command System
IMC	International Maritime Consultancy
ITOPF	The International Tanker Owners Pollution Federation Limited
JIBC	Justice Institute of British Columbia
KMC	Kinder Morgan Canada, Inc.
KPH	Kilometre per hour
MAC	Maximum acceptable concentration
MARPOL	International Convention for the Prevention of Pollution from Ships
MDCH	Michigan Department of Community Health
MMA	Montreal, Maine & Atlantic Railway
MMB/d	Millions of barrels per day

mPa·s	Millipascal-second
n.o.s.	Not otherwise specified
NAAQS	U.S. National Ambient Air Quality Standards
NAIT	Northern Alberta Institute of Technology
NCCEH	National Collaborating Centre for Environmental Health
NEB	National Energy Board
NFPA	National Fire Protection Association
NIEHS	U.S. National Institute of Environmental Health Sciences
NIH	U.S. National Institutes of Health
NIOSH	U.S. National Institute for Occupational Safety and Health
NOAA	U.S. National Oceanic and Atmospheric Administration
NRCan	Natural Resource Canada
NTSB	U.S. National Transportation Safety Board
NWAC	NW Area Committee Federal and State Spill Response Agencies
OECD	Organization for Economic Co-operation and Development
OSHA	U.S. Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbons
PG	Packing group
PHMSA	U.S. Pipeline and Hazardous Materials Safety Administration
PM	Particulate matter
PPE	Personal protective equipment
PTSD	Post-traumatic stress disorder
PubMed	PubMed search engine accessing the MEDLINE database, U.S. National Library of Medicine, NIH citations for biomedical literature
TC	Transport Canada
TDG	United Nations (UN) Transport of Dangerous Goods Model Regulations
TEEL	Temporary Emergency Exposure Levels
TSB	Transportation Safety Board
UN	United Nations
UVCB	Unknown or variable composition, complex reaction products and biological substances

VOC	Volatile organic compounds
WCSB	Western Canada sedimentary basin
WHO	World Health Organization
WTI	West Texas Intermediate

INTRODUCTION

Crude oil spills/releases, alone or in combination with combustion/explosion of the oil, have been the cause of several major disasters in Canada and around the world including the 2010 *Deepwater Horizon* oil spill and the 1989 grounding of the *Exxon Valdez* (see Table 16 for additional examples).

The 2013 Lac-Mégantic, QC derailment was the most significant disaster involving crude oil in Canadian history, and left 47 dead, a devastated community and significant environmental damage (see Section 4.1).

After the Lac-Mégantic disaster, the public health community and emergency management practitioners, as well as numerous groups involved in crude oil transport and use and concerned citizens, felt the need for a guidance document addressing the key features of crude oil incidents and their management.

This guidance document was prepared to fulfil this need, and is directed primarily at environmental public health and emergency management practitioners responsible for the public health management of chemical incidents. It is intended to assist in the development of emergency preparedness plans (notably awareness, education, and training activities) and in the design of scenarios for emergency exercises.

This guidance provides basic information on crude oil, its hazards, and its potential effects on health. The focus is primarily on acute exposure resulting from major incidents of public health concern.

The guidance is divided into four main sections, complemented by references and annexes, each of which can be consulted independently:

- **Section 1: Identification and Hazard Summary**
- **Section 2: Exposure and Health Effects Considerations**
- **Section 3: Public Health Risk Management**
- **Section 4: Case Studies**

Throughout the documents, **Boxes** are used to provide supplementary information on a specialized topic. **Checklists** (decision aids) for easy consultation to inform public health consequence management interventions are provided in section three.

During the response phase following notification of a crude oil incident, readers should consult up-to-date, specialized, and authoritative references and resources applicable to their jurisdiction.

Detailed technical information is provided in the references section. The majority of these reports are freely available on the Internet.

Section 1. IDENTIFICATION AND HAZARD SUMMARY

This section contains information on the labeling, physical and chemical properties, life cycle, and hazards of crude oil as compiled in reviews prepared by international organizations and institutions that classify chemicals and their toxicity.

1.1 What is crude oil and what are its commonly used identifiers?

1.1.1 Identity

The Chemical Abstracts Services (CAS) registry number for crude oil is 8002-05-9, as noted in Table 1; however, given the CAS number is not sufficiently specific to permit unambiguous identification, the CAS also provides an additional definition for crude oil:

"Crude oil is a complex combination of hydrocarbons, consisting predominantly of aliphatic, alicyclic, and aromatic hydrocarbons. Crude oil may also contain small amounts of nitrogen, oxygen, and sulphur compounds. This definition encompasses light, medium, and heavy petroleums, as well as the oils extracted from tar sands [CAS, 2014]."

On a shipping container (e.g., rail tank car) containing crude oil, the United Nations Committee of Experts on the Transport of Dangerous Goods number should appear in a white rectangle on a point placard. A placard for crude oil (UN1267) showing the UN Number, the UN Transport of Dangerous Good hazard class, and a hazard pictogram is illustrated in Figure 1(see also section 1.4.2).

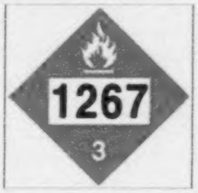


Figure 1: Placard for petroleum crude oil

1.1.2 Composition

Crude oil is comprised of hydrocarbons with carbon numbers ranging from C1 to C60+.

Additional minor constituents may include organo-metallic complexes, notably of sulphur and vanadium, and dissolved gases such as hydrogen sulfide.

Table 2 shows the elemental composition of an average crude oil sample [API, 2011a].

Table 1: Crude oil identifiers

Identifier		
Molecular formula	Unknown/variable	
Classification under the Globally Harmonized System of Classification and Labeling of Chemicals (GHS)	Chemical substance of unknown or variable composition, complex reaction products, and biological substances (UVCB)	
Common synonyms and trade names	Petroleum Petroleum crude Paraffinic oil	Earth Oil Rock Oil Zafiro
Chemical Abstracts Service Registry Number (CAS RN)	8002-05-9	
United Nations Committee of Experts on the Transport of Dangerous Goods number (UN number)	UN 1267 – Petroleum crude oil UN 3484 – Petroleum sour crude oil, flammable, toxic UN 1270 – Petroleum oil and waste petroleum oil	

Table 2: Elemental composition of an average crude oil sample by weight

Element	Percentage range	Element	Percentage range
Carbon	83 to 85 %	**Oxygen**	0.05 to 1.5 %
Hydrogen	10 to 14 %	**Sulphur**	0.05 to 6.0 %
Nitrogen	0.1 to 2 %	**Metals**	< 0.1 %

1.1.3 Classification

The term "crude oil" comprises a wide range of hydrocarbon mixtures. Crude oils range from thin, mobile, straw-coloured liquids consisting mainly of gasoline-like hydrocarbons (readily distilled at atmospheric pressure) to heavy, viscous, semi-solid, tar-like substances (from which little can be distilled at atmospheric pressure before thermal decomposition occurs). **Crude oil has therefore been generally defined as a substance with unknown or variable composition** (as have many other petroleum products).

Crude oils are roughly distinguished based on their density or American Petroleum Institute (API) gravity. API gravity is an arbitrary scale expressing the gravity or density of liquid petroleum products. The measuring scale is calibrated in terms of degrees API [EIA, 2017a].

Degrees API Gravity =
(141.5 / (specific gravity at 60°F)) – 131.5

Crude oil may be considered "light" if it has a high API gravity (low density) or "heavy" if it has low API gravity (high density).

Table 3 shows the currently accepted API gravity values for differentiating between light and heavy crude oils and those of alternative classification schemes.

Table 3: Types of crude oil

Type	API	International Marine Consultancy (IMC) [IMC, 2011]	Oil Prices.org [OP, 2016]
Conventional or "light" crude	Density-gravity range less than 934 kg/m³ (> 33° API)	> 31.1° API	≥ 40.1° API
Medium oil		between 22.3° API and 31.1° API	between 20° API and 40.1° API
"Heavy" crude oil	Density-gravity range from 1,000 kg/m³ to more than 934 kg/m³ (10° API to < 28° API) Maximum viscosity of 10,000 mPa.s (cp)	< 22.3° API	≤ 20° API
"Extra-heavy" crude oil; may also include atmospheric residua (b.p.>340 °C)	Density-gravity greater than 1 000 kg/m³ (< 10° API) Maximum viscosity of 10,000 mPa.s (cp)		
Tar sand bitumen (before upgrade) or natural asphalt; may also include vacuum residua (b.p.>510° C)	Density-gravity greater than 1,000 kg/m³ (< 10° API) Maximum viscosity of 10,000 mPa.s (cp)		

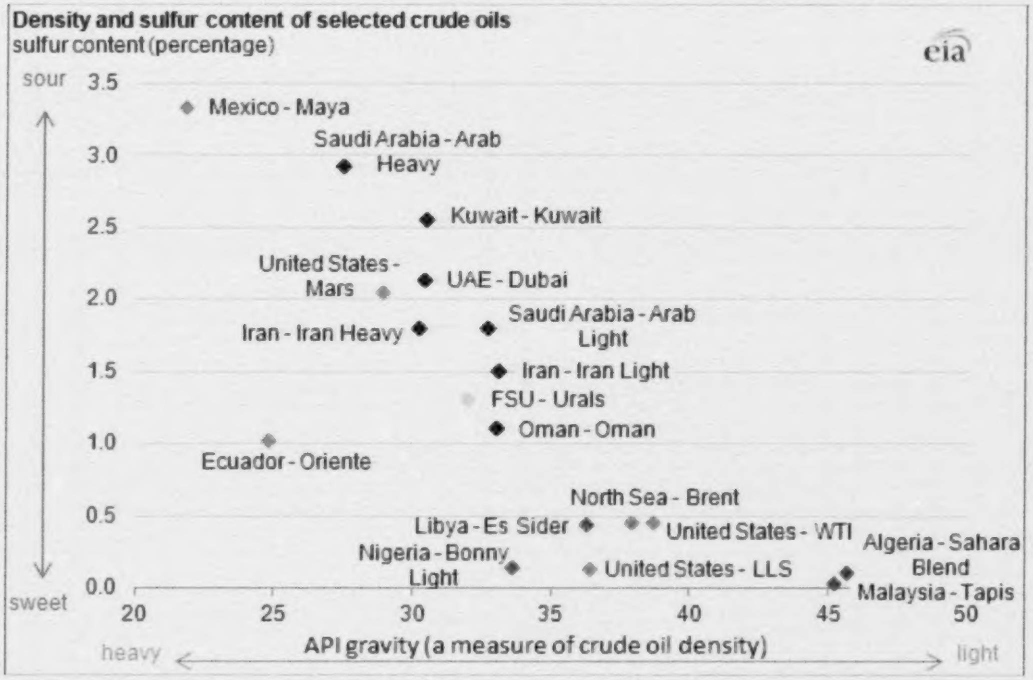
Crude oil may also be referred to as "**sweet**" if it contains less than 1% sulphur or "**sour**" if it contains greater than 1% sulphur [API, 2011b].

Crude oils are further classified based on the composition by weight of the various hydrocarbon molecules in the particular crude oil (see Table 4). Paraffinic crude oils are rich in straight-chain and branched paraffins. Naphthenic crude oils contain mainly naphthenic and aromatic hydrocarbons. Mixed base crude oils have varying amounts of each type of hydrocarbon [API, 2011a; Hyne, 2001].

The petroleum industry generally classifies crude oil by the geographic location in which it is produced, API gravity, and sulphur content (see Table 5 and Figure 2).

Table 4: Composition by weight of hydrocarbon molecules in crude oil

Hydrocarbon	Average	Range
Alkanes (paraffins)	30 %	15 to 60 %
Naphthenes	49 %	30 to 60 %
Aromatics	15 %	3 to 30 %
Asphaltics	6 %	Remainder



Notes: Points on the graph are labelled by country and benchmark name. The graph does not indicate price or volume output values. United States-Mars is an offshore drilling site in the Gulf of Mexico. WTI = West Texas Intermediate; LLS = Louisiana Light Sweet; FSU = Former Soviet Union; UAE = United Arab Emirates [EIA, 2012].

Figure 2: API gravity and sulphur content of selected crude oil

1.2 What are the physical properties of crude oil?

Due to their complex composition, crude oils vary widely in their physical and chemical properties. The melting point, boiling point, vapour pressure, partition coefficient, and water solubility of crude oils can differ between oil producing regions as well as within a specific production field [API, 2011a] (see Table 5 and Table 6 and Annex A: Composition and basic analysis of crude oils).

Table 5: Generic characteristics of crude oil components

Light-weight	Medium-weight	Heavy-weight
• High evaporation rates • A boiling range up to 150 degrees Celsius • High water solubility • High acute toxicity due to constituents such as benzene, toluene and xylenes • Highly flammable constituents (methane, ethane, propane and butanes, hydrogen sulphide) [CB&I, 2015]	• Slower evaporation rates • Low to no water-soluble fraction • Moderate acute toxicity • Alkanes which are readily degraded	• Low to no evaporation • Almost no water-soluble fraction • Potential for chronic toxicity due to poly-aromatic fractions • Long-term persistence

1.3 What is the flammability and reactivity of crude oil?

Crude oil is flammable. High temperatures and all sources of ignition should be avoided. Vapour accumulation should be prevented. When heated sufficiently or when ignited in the presence of air or oxygen, crude oil will burn exothermically to produce carbon dioxide and water [CAMEO, 2013].

Crude oil does not react with aqueous solutions of acids, alkalis, most oxidizing agents, and most reducing agents. However, strong oxidizing agents (e.g., nitric acid) should be avoided [CAMEO, 2013].

1.4 How are crude oil products and their hazards identified on shipping and storage containers?

1.4.1 2016 Emergency Response Guidebook (ERG)

The 2016 Emergency Response Guidebook (ERG) places petroleum crude oil (UN 1267) in Guide 128: Flammable Liquids (Water-Immiscible). It places Petroleum sour crude oil, flammable, toxic (UN 3494) in Guide 131: Flammable Liquids – Toxic. Materials included under UN 1270 are covered in Guide 128 [ERG, 2016] (see Table 7).

Table 6: Physical properties of crude oil

Property		
Physical state (20°C)	Liquid	
Colour	Light, mobile, straw-coloured liquid to highly viscous, semi-solid black substance	
Odour	Potential smell of rotten eggs and sulphur	
Density (gm/cm^3 at 20°C)	Norman Wells crude oil	0.832 [HSDB, 2011]
	Alberta crude oil	0.835 [HSBD, 2011]
	Prudhoe Bay crude oil	0.90 [HSDB, 2011]
	Hibernia B crude oil	0.837 [HSDB, 2011]
	Bakken crude	0.7–1.03 [ConocoPhillips, 2014]
Specific gravity	Bakken crude	0.7–0.8 [Cenovus, 2012]; 0.7–1.03 at 15.6 C [ConocoPhillips, 2014]
Initial Boiling Point and Boiling Range (°C)	Unspecified	-1 to 565 [HSDB, 2011]
	Bakken crude	-40 to 530 [Cenovus, 2012]
	Wabasca cude	-18 to 400+ [Cenovus, 2014a]
Melting point (°C)		-30 to 30 [HSDB, 2011]
Flash point (°C)	Bakken crude	<-35 [Cenovus, 2012] <-29 [ConocoPhillips, 2014]
	Wabasca crude	<-5 [Cenovus, 2014a]
Solubility (based on total benzene, toluene, ethylbenzene + xylenes (combined concentration) and naphthalenes concentrations) (g/L at 22°C)	Norman Wells crude oil	30–33.5 (distilled water) [HSDB, 2011] 14.8–25.5 (seawater) [HSDB, 2011]
	Alberta crude oil	25.02 (distilled water) [HSDB, 2011]
	Swan Hills crude oil	35.1 (distilled water) [HSDB, 2011]
	Prudhoe Bay crude oil	29.01 (distilled water) [HSDB, 2011]
	Hibernia B crude oil	16.92 (seawater) [HSBDB, 2011]
	Hibernia J crude oil,	7.75 (seawater) [HSDB, 2011]
Vapour pressure (kPa)	Alaska North Slope	19 at 37.8°C [HSDB, 2011]
	Atkinson Beaufort Sea	6 at 37.8°C [HSDB, 2011]
	Alberta Sweet Mixed Blend	19 at 37.8°C [HSDB, 2011]
	Bakken	37–48 at 20°C [Cenovus, 2012]
	Wabasca crude heavy	45–65 at 37.8°C [Cenovus, 2014a]
	Beryl (North Sea, USA)	36 at 37.8°C [HSDB, 2011]
Vapour Density (Air = 1.0)	Wabasca crude	2.5 -5.0 (estimated) [Cenovus, 2014a]
	Bakken crude	1–3.9 [Keystone, 2014] 2.5–5.0 (estimated) [Cenovus, 2012]
Viscosity (mm^2/s)	Bakken crude	5.43 [Keystone,2014]

Note: Vapour pressure and water solubilities of crude oil fractions are given in HSDB. Enbridge, Inc. (EI) provides physical property data (density at 15°C, sulphur by weight, pour point, viscosity at 10, 20, 30, 40 and 45°C) for crude oils transported in its pipelines [EI, 2016]. HSDS and producer Safety Data Sheets (SDS) contain additional data. Additional information on Bakken crude oil is given in references AFPM, 2014 and NWAC, 2015.

Table 7: Principal hazards given in ERG Guide 128 for petroleum crude oil (UN1267) and in ERG Guide 131 for petroleum sour crude oil, flammable, toxic (UN3494)

Hazard	Petroleum crude oil Guide 128—Flammable Liquids (Water-immiscible)	Petroleum sour crude oil Guide 131—Flammable Liquids—Toxic
Health	• Inhalation or contact with material may irritate or burn skin and eyes. • Fire may produce irritating, corrosive, and/or toxic gases. • Vapours may cause dizziness of suffocation.	• TOXIC; may be fatal if inhaled, ingested, or absorbed through skin • Inhalation or contact with some of these materials will irritate or burn skin and eyes. • Fire will produce irritating, corrosive, and/or toxic gases.
Fire and Explosive	• HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks, or flames. • Vapours may form explosive mixtures with air. • Vapours may travel to source of ignition and flash back.	

1.4.2 UN Transport of Dangerous Goods Model Regulations (TDG)

The UN Recommendations on the Transport of Dangerous Goods (TDG) Model Regulations, 17th Edition, places Petroleum crude oil (UN1267) in Class 3 (flammable liquids–liquids with flash point less than or equal to 60°C [closed cup test]). Petroleum sour crude oil (flammable and toxic) (UN3494)-containing sufficient hydrogen sulfide, where vapour from the crude oil presents an inhalational hazard, is placed in Class 3 with Subsidiary Risk 6.1 (Toxic Substances—substances liable either to cause death or serious injury or to harm human health if swallowed or inhaled, or by skin contact) (see Figure 3) [TDG, 2011].

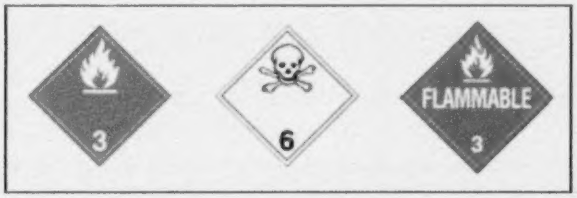


Figure 3: Generic TDG placards applicable to crude oil

TDG also assigns a packing group (PG) to each material. The packing group classifies the material by the amount of risk it poses during transportation. The packing group also determines the degree of protective packaging required. The packing group is determined by flammability and inhalation hazards in accordance with the degree of danger presented (see Table 8).

Table 8: Packing Groups for Class 3 Flammable Liquids

Packing Group	Definition	Flash Point (closed cup test) (°C)	Initial Boiling Point (°C) at absolute pressure of 101.3 kPa
I	Substances presenting high danger	any flash point	less than or equal to 35°C
II	Substances presenting medium danger	less than 23°C	greater than 35°C
III	Substances presenting low danger	between 23°C and 60°C	greater than 35°C

The TDG stats that Petroleum crude oil (UN1267) and Petroleum sour crude oil flammable, toxic (UN3494) can be assigned to PG I, II, or III. The correct PG assignment can be made only after tests are conducted on each oil shipment (see TDG, 2011 Part 2 for a detailed discussion of tests required).

After the Lac-Mégantic derailment (see Section 4.1), concern was raised that the correct Packing Group was not being consistently assigned to Bakken crude oil [Mcinish, 2013; TSB, 2013]. On 17 October 2013, Transport Canada (TC) stated that crude oil (UN 1267), shipped by rail, must be classified as a Class 3 Flammable Liquid PG I [TC, 2013]. Regulation changes resulting from the Lac-Mégantic derailment are discussed in Section 4.1 and Annex M: Changes in regulations involving the transportation of crude oil in Canada and the United States resulting from the Lac-Mégantic derailment (not exhaustive).

On February 2014, after derailment and fire at Casselton, ND, the U.S. Department of Transportation (DOT) issued an Emergency Restriction/Prohibition Order requiring that all Class 3 (Flammable Liquid) crude oil be shipped as PG I or PG II until further notice [DOT, 2014].

1.4.3 Globally Harmonized System of Classification and Labeling of Chemicals (GHS)

The Globally Harmonized System of Classification and Labeling of Chemicals (GHS) was developed by the United Nations to provide an internationally harmonized approach to classification and labeling of chemicals [GHS, 2013]; and was implemented in Canada in 2015 [CCOHS, 2015; GC, 2014].

The GHS recognizes that there are many different types of crude oil, each consisting of many thousands of chemicals (predominantly hydrocarbons) and that no two crude oils share the same composition. Petroleum substances are, therefore, placed in the general class "chemical substances of unknown or variable composition, complex reaction products and biological substances" (UVCB substances, see Table 1).

Many companies have produced Safety Data Sheets (SDS) giving GHS classification, labelling, and pictograms for the particular type of crude oil they produce.

Table 9 shows the GHS information for Bakken crude oil (light, sweet) from the 2014 Safety Data Sheet produced by ConocoPhillips [ConocoPhillips, 2014]. The GHS precautionary statements that give advice about the correct handling of crude oil (prevention, response, and disposal) are listed on the SDS.

The principal difference in the GHS classification between heavy crude and light crude is in flammability. Light crude is classified as Flammable Liquid Category 1, whereas heavy crude oil is classified as Flammable Liquid Category 2.

1.4.4 National Fire Protection Association

The U.S.-based National Fire Protection Association has developed a scoring system to help fire and emergency responders and safety personnel easily identify the hazards of short-term/acute exposure to commonly encountered industrial chemicals in the event of a fire, spill, or similar emergency [NFPA, 2012].

The hazards of a material and the degree of severity of the health, flammability, instability and special hazards are displayed on the NFPA diamond (actually a square on point; see Figure 4) as follows: health (blue) at the nine o'clock position, flammability (red) at twelve o'clock position, instability (yellow) at three o'clock position, and special hazards (white) at the six o'clock position.

Use of NFPA diamonds and scores are voluntary in Canada. Diamonds are most often found on fixed facilities and, in the United States, are not allowed on bulk containers while in transit.

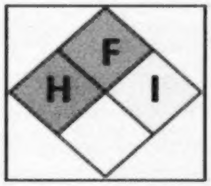
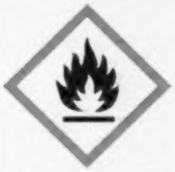
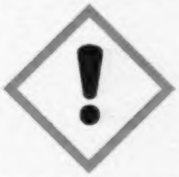
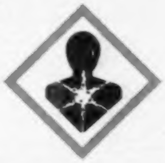


Figure 4: NFPA diamond

Table 9: Example of a GHS classification and labelling for sweet Bakken crude oil

Classification			**Labeling**	
Hazard Class and Category Code	**Hazard Statement Code**	**Hazard Statement**	**Pictogram Codes**	**Pictogram**
Flammable liquid Category 1 (Flam. Liq. 1)	H224	Extremely flammable liquid and vapour (flash point less than 23°C and initial boiling point less than or equal to 35°C).	GHS02	
Specific target organ toxicity (single exposure) Category 3 (STOT SE 3)	H336	May cause drowsiness or dizziness.	GHS07	
Eye irritant Category 2 (Eye Irrit. 2)	H319	Causes serious eye irritation.		
Carcinogenicity Category 1B (Carc. 1B)	H351	Suspected of causing cancer.	GHS08	
Specific Target Organ Toxicity, Repeated Exposure Category 2 (STOT RE 2)	H373	May cause damage to organs or organ systems through prolonged or repeated exposure.		
Aspiration Hazard Category 1 (Asp. Tox 1)	H304	May be fatal if swallowed and enters airways.		

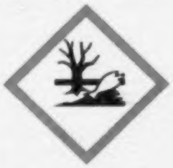
Classification			Labeling	
Hazard Class and Category Code	**Hazard Statement Code**	**Hazard Statement**	**Pictogram Codes**	**Pictogram**
Hazardous to the aquatic environment, long-term, chronic Category 2 (Aquatic Chronic 2)	H411	Toxic to aquatic life with long-lasting effects.	GHS09	
Signal Word	Danger			
Hazards Not Otherwise Classified: May contain or release poisonous hydrogen sulfide gas [ConocoPhillips, 2014]				

Table 10: NFPA scores for crude oils

Crude oil type	Producer	Health	Flammability	Instability	Special Hazards
Bakken crude (light)	Cenovus, 2012	3 (Warning–corrosive or toxic; avoid skin contact or inhalation)	4 (Danger–extremely flammable liquid)	0 (Stable)	
Bakken crude	ConocoPhillips, 2014	2 (Warning–may be harmful if inhaled or absorbed)	3 (Warning–flammable liquid flash point below 100 °F)	0	Personal protection
Wabasca heavy crude oil	Cenovus, 2014a	1 (Caution–may be irritating)	3	0	
Cold Lake blend crude oil	Cenovus, 2014b	1	3	0	
Christina Lake dilbit blend	Cenovus, 2014c	1	3	0	
Crude oil, sweet	ConocoPhillips, 2014	1	3	0	
Note: Dilbit Blends are made from heavy crudes and/or bitumens and a diluent, usually condensate, for the purpose of meeting pipeline viscosity and density specifications, where the density of the diluent included in the blend is less than 800 kg/m^3 [CAPP, 2016].					

1.5 What is the life cycle of crude oil?

1.5.1 Sources

Petroleum is a fossil fuel derived from ancient fossilized organic materials, such as zooplankton and algae that have undergone hydrocarbon pyrolysis as a result of a variety of mainly endothermic reactions at high temperature or pressure. Over millions of years, vast quantities of organic matter settled to sea and lake bottoms, where they mixed with sediments, and were buried under anoxic conditions. As further layers settled to the sea or lake bed, intense heat and pressure built up in the lower regions causing the organic matter to change, first into a waxy material known as kerogen—which is found in various oil shales—and then, with more heat, into liquid and gaseous hydrocarbons through a process known as catagenesis [Braun, 1993].

1.5.2 Production and Extraction

Conventional oil is recovered by drilling wells through the non-porous rock barrier that traps the underlying oil. About 30% of the trapped oil can be economically recovered by pumping. "Secondary" recovery can remove another 10%, by flooding the well with high-pressure water or gas. Another 10% can sometimes be recovered with "tertiary" methods that heat the oil to scrub it out [API, 2011a].

Hydraulic fracturing (fracking) is a well-stimulation technique in which rock is fractured by a pressurized liquid. The "fracking fluid"—primarily water containing sand, or other proppants suspended with the aid of thickening agents—is injected at high pressure into a wellbore to create cracks in the deep-rock formations through which natural gas, petroleum, and brine will flow back to the well more freely. When the hydraulic pressure is removed from the well, small grains of hydraulic fracturing proppants (either sand or aluminium oxide) hold the fractures open. Bakken crude oil is recovered by fracking [NWAC, 2015].

1.5.3 Refining

The oil refining process separates crude oil into different hydrocarbons and removes impurities such as sulphur, nitrogen, and heavy metals. The first step is fractional distillation, a process that takes advantage of the fact that different hydrocarbons boil at different temperatures. In a tall tower called a fractionating column, crude oil is heated until it boils. Horizontal trays divide the column at intervals. As the oil boils, it vaporizes. Each hydrocarbon rises to a tray at a temperature just below its own boiling point where it cools and turns back into a liquid.

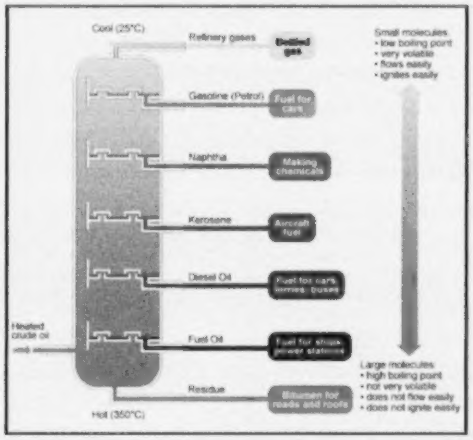

Cool (25°C)
Refinery gases
Bottled gas
Gasoline (Petrol)
Fuel for cars
Naphtha
Making chemicals
Kerosene
Aircraft fuel
Diesel Oil
Fuel for cars, lorries, buses
Heated crude oil
Fuel Oil
Fuel for ships, power stations
Residue
Bitumen for roads and roofs
Hot (350°C)
Small molecules
• low boiling point
• very volatile
• flows easily
• ignites easily
Large molecules
• high boiling point
• not very volatile
• does not flow easily
• does not ignite easily

Figure 5: Crude oil components

The lightest fractions are liquefied petroleum gases (propane and butane) and the petrochemicals used to make plastics, fabrics, and a wide array of consumer products. Next come gasoline, kerosene, and diesel fuel. Heavier fractions make home heating oil and fuel for ships and factories. Still heavier fractions are made into lubricants and waxes. The remains include asphalt [API, 2011a] (Figure 5 [CB&I, 2015]).

1.6 Where is crude oil produced?

Crude oil is a high production volume chemical (HPV) [OECD, 2009].

In 2016 the United States led the world in crude oil production, producing 14,855,000 barrels per day (bbl/d). Saudi Arabia was second (12,379,000 bbl/d), followed by Russia

(11,220,000 bbl/d), China (4,868,000 bbl/d) and Canada (4,594,000 bbl/d). Detailed data on production, consumption and proven reserves is available on the U.S. Energy Information Administration website [EIA, 2017a].

In Canada, there are two major oil producing areas: the Western Canada Sedimentary Basin (WCSB)—a large basin that extends from southwestern Manitoba to southern Saskatchewan, Alberta, northeastern British Columbia, and the southwest corner of the Northwest Territories—and offshore eastern Canada. Oil is also produced in modest volumes in Ontario and the Northwest Territories.

More than 95% of Canada's established oil reserves are in the form of **oil sands**. The oil sands are a mixture of crude bitumen (a semi-solid form of crude oil), silica sand, clay minerals, and water. The oil sands deposits are in the Athabasca, Cold Lake, and Peace River areas of Alberta. The National Energy Board (NEB) 2016 estimated production of Canadian crude oil and equivalent is shown in Table 11[NEB, 2017a].

There are three major crude oil production projects off Newfoundland and Labrador—Hibernia, Terra Nova, and White Rose. The Hibernia field, which is located in the Jeanne d'Arc Basin, 315 km east of St John's, NF in a water depth of 80 metres, consists principally of two early Cretaceous reservoirs—Hibernia and Avalon—located at average depths of 3,700 metres and 2,400 metres, respectively. The Terra Nova field is located on the northeastern Grand Banks, approximately 350 km southeast of St. John's, NF, in a water depth of about 90 to 100 metres. The White Rose field is located on the northeastern Grand Banks approximately 50 km from both the Terra Nova and Hibernia fields in a water depth of about 120 metres. The White Rose Development focuses on the South Avalon pool [Offshore Technology, 2017].

The Bakken Formation is an interbedded sequence of black shale, siltstone, and sandstone that underlies large areas of northwestern North Dakota, northeastern Montana, southern Saskatchewan, and southwestern Manitoba [Geology, 2014].

Alberta produces 41.7% of the conventional light crude oil, Newfoundland/Labrador 26.7%, and Saskatchewan 22.2%.

Table 11: 2016 Estimated productions of Canadian crude oil and equivalent

Oil type	Average Estimated Production (m^3/d)
Light crude oil	
Conventional. light crude oil	124,950
Alberta upgraded bitumen	148,276
C5+ / condensate/	41,833
Total light crude oil	**315,059**
Heavy crude oil	
Alberta conventional	18,709
Alberta non-upgraded bitumen	236,743
Alberta sub total	255,452
Saskatchewan conventional	45,247
Total heavy crude oil	**300,699**
Total production	**615,758**

1.7 What is crude oil used for?

Petroleum products derived from crude oil include transportation fuels, fuel oils for heating and electricity generation, asphalt, and road oil, and the feedstock used to make chemicals, plastics, and synthetic materials.

In 2015, Canada used 1.9 million barrels of refined petroleum products per day [CAPP, 2017a]. In 2013 gasoline accounted for 42% of domestic sales of refined petroleum products, diesel 28%, aviation fuel 7%, heavy fuel oil 3%, heating oil 2%, and other products (propane, butane, petro-chemical feedstocks, lubricating oils, petroleum coke, and asphalt, etc.) 18% [NRCan, 2014].

In 2016, the United States produced about 14.6 million barrels per day (MMb/d) of petroleum, and consumed about 19.6 MMb/d of petroleum. The five largest sources of U.S. petroleum imports by share of total imports in 2016 are Canada (38%), Saudi Arabia (11%), Venezuela (8%), Mexico (7%), and Columbia (5%) [EIA, 2017b].

1.8 How is crude oil transported?

Crude oil is shipped by pipeline, rail, road, tanker, and barge. In both the United States and Canada, more crude oil, petroleum products, and natural gas are transported in pipelines than by all other modes combined (using the unit of ton-mile, which is the number of tons shipped over number of miles). In 2015, United States refineries received 61% of their crude by pipeline [EIA, 2016]. The NEB data on Canadian crude oil exports by export transportation system shows that the vast majority was shipped by pipeline.

In Canada, large refineries (> 20,000 m^3/d) are located at St John, NB; Levis, QC; Montreal, QC; Regina, SK; and in the Edmonton, AB area. The CAPP provides detailed information on Canadian refining capacity [CAPP, 2017a].

1.8.1 Pipeline

Pipelines[1] are divided according to their purpose: gathering lines transport oil from wells and mines to gathering facilities; feeder lines bring oil from processing facilities to the long-distance pipelines called transmission lines. Four major pipelines move western Canadian crude out of the Western Canada Sedimentary Basin. The Enbridge Mainline pipeline and the Kinder Morgan Trans Mountain pipeline originate at Edmonton, AB, while the Spectra Express pipeline and the TransCanada Keystone pipeline originate at Hardisty, AB. These pipelines provide about 4 million barrels/day of capacity out of Western Canada (see Annex B: Crude oil pipelines in Canada and the United States for map showing pipelines in Canada and United States and references CAPP, 2017b and NEB, 2017c for more detailed information).

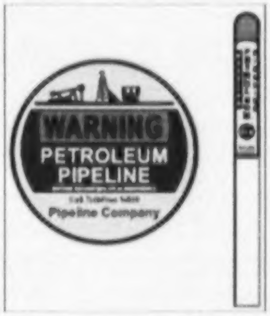


Figure 6: Marker indicating the presence of a petroleum pipeline

Markers indicating the presence of a transmission pipeline often appear at road, railroad, and water crossings, and may be posted at property boundaries (see Figure 6). Signs include operator emergency Points of Contact and product transported. Warning,

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[1] The National Energy Board (NEB) regulates pipelines that cross inter-provincial or international boundaries, including 73,000 kilometres of inter-provincial and international pipelines within Canada

Caution, or Danger appears on signs [see ERG, 2016 for discussion and other markers].

1.8.2 Rail

Traditionally, crude oil was shipped by pipeline in North America. However, the growing production of shale oil from the Bakken fields in North Dakota and Montana, coupled with the slow construction of new oil pipelines, has greatly increased shipment by rail. Crude oil is commonly shipped in unit trains of 70 or more cars, which constitute a virtual pipeline [Stancil, 2012; Stancil, 2014].

In the United States, freight railroads carried 23,786,000 barrels of crude oil in 2010, rising to a peak of 382,033,000 barrels in 2014 and then decreasing to 174,539,000 barrels in 2016 [EIA, 2017c].

Canadian exports of crude oil by rail were 16,963,521 barrels in 2012, rising to a peak of 58,772,622 barrels in 2014, and then falling to 32,162,711 barrels in 2016 [NEB, 2017b].

Crude oil is transported in DOT-111 tank cars (non-pressure, insulated, or non-insulated, without an expansion dome)[2] (see Figure 7).

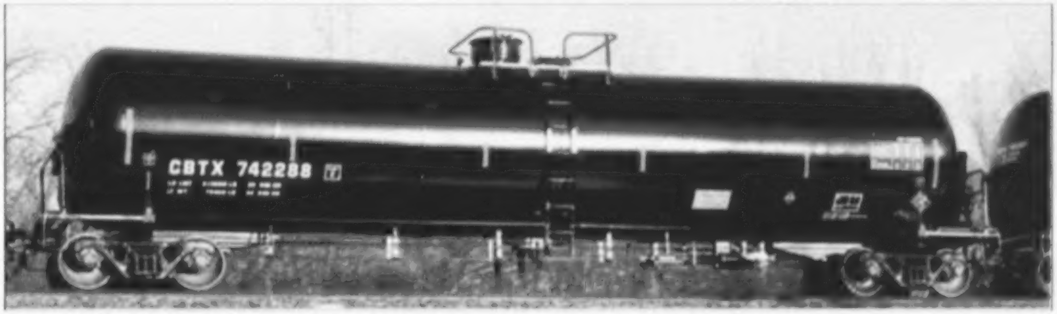

Figure 7: DOT-111 Tank Car

DOT-111 cars may be used to transport both regulated (hazardous materials/dangerous goods) and unregulated commodities. In 2014, there were approximately 228,000 DOT-111 tank cars currently in service in North America with approximately 92,000 of these in flammable liquid service[3] [GPAC, 2014].

By Association of American Railroads rules, all DOT-111 tank cars ordered on or after October 1, 2011, for petroleum, crude oil, and ethanol included in PG I and II must have additional safety features that include top-fitting protection, half head shields, increased thickness of the heads and the shell for non-jacketed tank cars, and mandatory use of normalized steel. There are approximately 26,000 of these newer style tank cars, designated CPC-1232, currently in service [GPAC, 2014].

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[2] Class DOT-111 tank cars made of carbon or alloy (stainless) steel are required to have a minimum shell thickness of 7/16 inch, and those made of aluminum alloy are required to have a minimum shell thickness of 1/2 inch (60 psig tank test pressure) or 5/8 inch (100 psig tank test pressure). Regardless of the material of construction, DOT-111 tank car tanks with a 60 psig tank test pressure are required to have a minimum burst pressure of 240 psig, and those with a 100 psig tank test pressure are required to have minimum burst pressure of 500 psig. DOT-111 carbon and alloy steel tanks and welded attachments must be post-weld heat treated as a unit. Tank car made of aluminum alloy are not allowed to be post-weld heat treated. DOT-111 non-pressure tank cars that haul crude oil require a lining with acid-resistant rubber or other approved rubber compound vulcanized or bonded directly to the metal tank. Detailed specifications are given in the U.S. Code of Federal Regulations (CFR) [CFR, 2014].

[3] Generally, DOT-111 tank cars cannot exceed 34,500 gallons in capacity or 263,000lbs in gross weight on rail. At Bakken crude oil's highest density of 39.7° API, the tank car can only hold 30,488 gallons (211,100 lbs) – a volume reduction of roughly 1,300 gallons. The reduced volume also creates free space at the top of the tank car, which provides the opportunity for entrained gases to release from crude oil [Andrews, 2014]

DOT-111 tank cars were involved in several hazardous material accidents before the Lac-Mégantic derailment (e.g., 2009 Cherry Valley ethanol derailment [NTSB, 2012a]). Deficiencies in DOT-111 tank cars design are discussed and illustrated in presentations by Stancil [Stancil, 2012; Stancil, 2014].

1.8.3 Ship

There are two types of oil tankers: crude carriers for unrefined products and product carriers for refined products. Crude tankers are mainly used to transport crude oil from production areas in the Arabian Gulf and West Africa to refineries in Asia, Europe, and the United States. Product tankers are used to transport refined oil products (e.g., gasoline, diesel, kerosene, jet, or fuel oil) to the market.

The Average Freight Rate Assessment system and the Flexible Market Scale system classify tankers according to different sizes (see Annex C: Classification of tankers according to size).

International Convention for the Prevention of Pollution from Ships (MARPOL) regulations require that all oil tankers built after July 1996 have a double hull and that older vessels be phased out [MARPOL, 1992].

In Canada, shuttle tankers[4] are used to transport crude oil from the Hibernia, Terra Nova, and White Rose fields to the trans-shipment terminal located at Whiffen Head, NL.

1.9 What happens when crude oil is released into the environment?

Routine human activities (e.g., extracting, processing, refining), accidental releases and natural features such as oil seeps and tar pits release crude oil into the environment.

Crude oil may be spilled on land, into fresh water or into seawater. The physical and chemical characteristics of the oil will interact with the physical and biochemical features of the habitat where a spill occurs.

Once released into the environment, the major **migration pathways** of crude oil chemical constituents include the following [CB&I, 2015]:

- Evaporation, volatilization and dispersion into the air;
- Infiltration into soil in the immediate vicinity of the release;
- Direct surface release or overland runoff from release location to streams, rivers, lakes, coastal water areas, outer harbours, open water, ditches, wetlands and storm/ sanitary sewers; and
- Transport in groundwater, after leaching through soil saturated with crude oil.

The physical and chemical changes that spilled oil undergoes over time are collectively known as **weathering** [ITOPF, 2014a; HSDB, 2011; ASM, 2011; API, 2011a; API, 2011b]. These include evaporation, dispersion, dissolution, oxidation, emulsification, spreading, biodegradation, and sedimentation, including oil-particle aggregate formation.

The individual processes causing these changes may act simultaneously, with their relative importance varying in time. Together, these processes affect the behaviour of the oil and determine its ultimate fate.

In general, those oil components with a boiling point below 200°C will evaporate within 24 hours in temperate climates [ITOPF, 2014a; ASM, 2011; NOAA, 2014].

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[4] The tankers are described as twin skeg, twin screw shuttle tankers with 12 cargo tanks, two slop tanks, 13 segregated ballast tanks and bow loading system on the forecastle deck. The length is 271.8 m and the deadweight (at summer draft) 125,826.8- 126,646.6 tonnes [Canship Ugland Limited, 2017].

Components of crude oil, when released into the environment, will partition into various environmental compartments. The lower molecular weight components may dissolve in water or volatilize to the atmosphere. Intermediate fractions may float and spread out on water, where they may form emulsions and/or adsorb to soil and sediment. The viscous, heavy components may agglomerate and float or sink in water or adhere to soil and sediment. The rate at which partitioning occurs depends not only on the nature of the crude oil but also on the severity of the weathering processes it encounters [ITOPF, 2014a; ASM, 2011].

When components of crude oil disperse, they may undergo further chemical and physical transformations. Constituents that partition to the air interact with hydroxyl radicals, ozone and other free radicals in the atmosphere and thus are subject to indirect photo-degradation. Atmospheric half-life ranges from 0.4 days (e.g., n-dodecane) to 6.5 days (e.g., benzene) [ASM, 2011; NOAA, 2014].

Crude oils are subject to **biodegradation**, but biodegradation rates vary considerably, and may not be fast enough to prevent ecological damage. Factors influencing the rate of biodegradation include the physical state of the oil, the chemical nature of the oil, the availability of nutrients required by the microbes (e.g., nitrogen and phosphates), the availability of oxygen, and the temperature of the medium (e.g., water). Low molecular weight components may readily biodegrade, but as molecular weight increases, hydrocarbons become increasingly insoluble in water, so that their bioavailability is limited. In general, hydrocarbons are regarded as being inherently biodegradable, although the degradation rates of the more complex, high molecular weight fractions may be very slow [ASM, 2011; API, 2011a; Bieollo, 2010].

Section 2. EXPOSURE AND HEALTH EFFECTS CONSIDERATIONS

This section provides a general overview of the principal toxic constituents of crude oil, human exposure routes, the potential for acute or chronic health effects due to spill exposure, and health-protection standards and guidelines.

Additional physical effects related to explosion and/or combustion of crude oil are discussed briefly, as are the implications for the mental health of affected individuals or communities (see Figure 8). Health effects due to repeated or long-term exposure (as might be observed in occupational settings) are not covered here. Readers requiring detailed medical or clinical guidance should consult the appropriate literature.

2.1 Which constituents of crude oil may present a risk to human health?

Crude oil is classified as a chemical substance of unknown or variable composition (see Section 1.1).

Components of particular concern include [Levy, 2011; Goldstein, 2011; CDC, 2010a; Eykelbosh, 2014; Crudemonitor, 2017]:

- **Hydrogen sulfide (sour crude);**
- Volatile organic compounds (**VOCs**), including **alkanes**, and **benzene, toluene ethylbenzene, and xylenes (BTEX)**;
- **Polycyclic aromatic hydrocarbons (PAHs)**; and
- **Heavy metals** (e.g., mercury, vanadium, cadmium and nickel).

In addition, the **chemical dispersants** that are widely used to break up oil spills in water [Helton, 2018] may pose risks to human health either directly or as a result of altering the exposure routes for and bioavailability of various toxic chemicals contained in the dispersed oil.[5]

2.2 What are the pathways of exposure?

Persons can be exposed to crude oil (and other chemicals from the oil spill) or combustion by-products by one or all of the following routes [ATSDR, 1999; Jung, 2017; Goldstein, 2011]:

- **Inhalation** of vapours and aerosols;
- **Ingestion** of contaminated soils (incidental or pica), food and/or water, or as a result of hand- or object-to-mouth behaviour, or incidental ingestion of crude oil aerosols and/or mucociliary clearance of inhaled aerosols; and
- Direct **eye or skin** contact with free crude oil or vapour, or contact with contaminated water, soils or sand/sediments, alone or in combination.

The total exposure would include the aggregated exposure across all routes as well as the cumulative exposure, which is the total exposure to multiple hydrocarbon compositions with a common mode of action.

2.3 What are the potential health effects resulting from major crude oil incidents?

Potential health effects in humans from crude oil spills, releases, combustion and/or explosions include physical, toxicological, and mental effects, as well as community health impacts (see Figure 8). Whereas many physical and toxicological impacts may be reversible and of short-duration [Na, 2012], mental health and community impacts may be prolonged.

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[5] The use of the chemical dispersants Corexit® EC9500A and Corexit® EC9580A as spill-treating agents is permitted in Canada [CG, 2016].

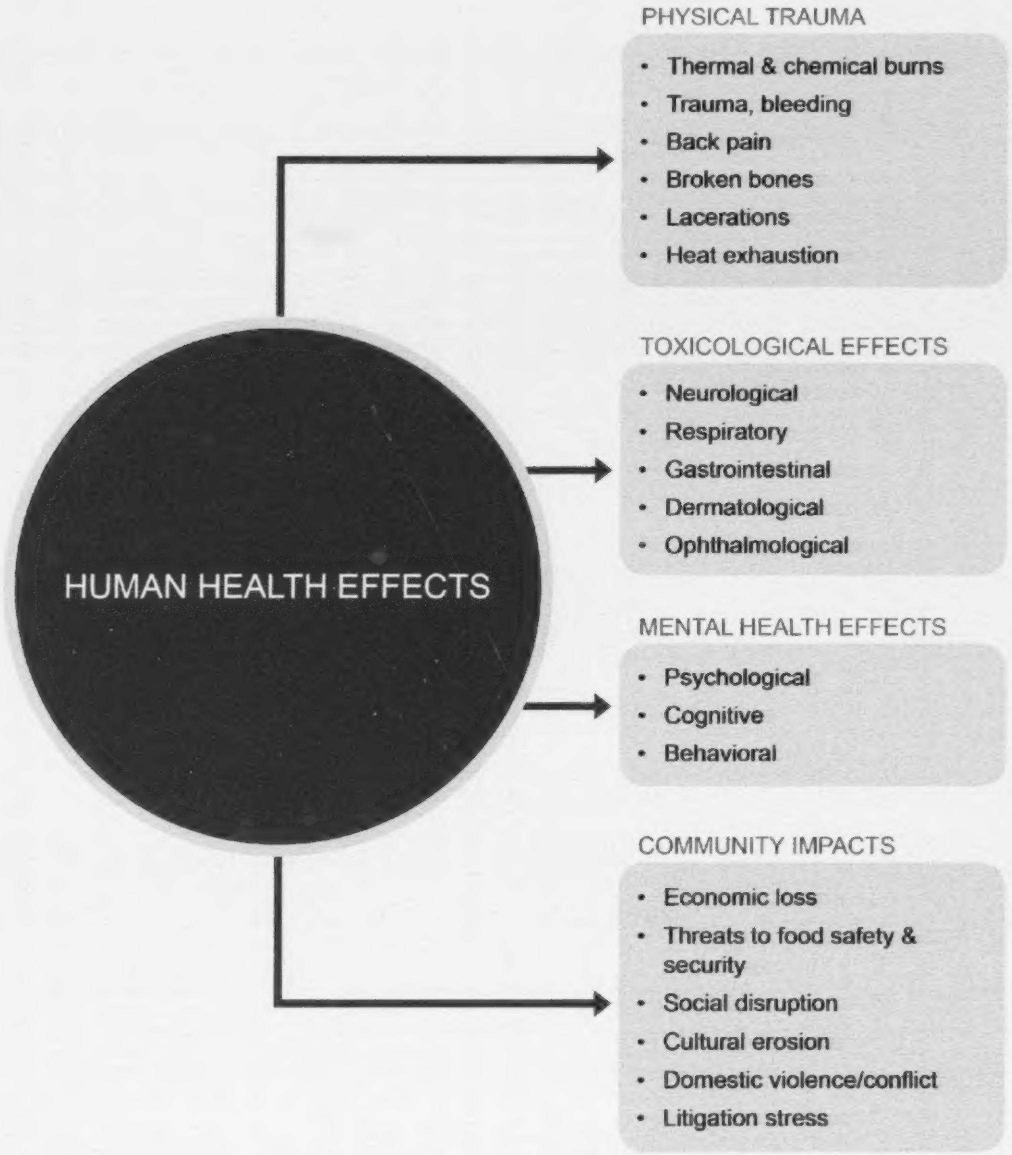
HUMAN HEALTH EFFECTS
PHYSICAL TRAUMA
Thermal & chemical burns
Trauma, bleeding
Back pain
Broken bones
Lacerations
Heat exhaustion
TOXICOLOGICAL EFFECTS
Neurological
Respiratory
Gastrointestinal
Dermatological
Ophthalmological
MENTAL HEALTH EFFECTS
Psychological
Cognitive
Behavioral
COMMUNITY IMPACTS
Economic loss
Threats to food safety & security
Social disruption
Cultural erosion
Domestic violence/conflict
Litigation stress

Figure 8: Observed/documented oil spill-induced acute and chronic human health effects

2.3.1 Physical trauma

If an explosion and/or a fire is the cause of the release or its result, an exposed person may suffer from direct thermal and chemical burns to the skin, eyes, and lungs, as well as potential traumatic injuries, bleeding, shock, and death. Explosion and fire was the cause of death of 47 persons in the Lac-Mégantic derailment (see section 4.1 and Toxicology of burning oil, below). Exposed persons may also suffer from smoke inhalation as a direct result of the burning oil, the burning of other materials in the vicinity, and volatilization of toxic chemicals in the environment (see Sheridan, 2016 for a discussion of inhalation injuries related to fire).

2.3.2 Toxicological effects

Crude oil spill materials are a diverse family of compounds with a wide spectrum of toxicities. This subsection provides a summary of crude oil acute health effects and carcinogenicity. Non-cancer and chronic health effects considerations, such as reproductive and developmental toxicity, are beyond the scope of this document. However, it is important to note that the compounds discussed do possess many of these other toxicology attributes and human exposure may result in a range of negative health outcomes.

Acute effects

Acute exposure during a spill may lead to neurological (central and peripheral nervous systems), respiratory, gastrointestinal, dermatological (skin), and ophthalmological (eye) complications. The effects are dose- and duration-dependent, and among clean-up workers dependent on the proper use of PPE [Suarez, 2005].

In a meta-analysis of 13 studies of acute exposure in seven oil spills[6], the reported toxicological symptoms in order of decreasing frequency were: respiratory, ophthalmological, headache, dermatological, nausea, dizziness, and tiredness or fatigue [Levy, 2011, Table 3] (see also Annex D: Examples of reported toxicological health effects from acute crude oil exposure and Annex E: Epidemiological studies on physical/physiological effects experienced by humans exposed to oil spills).

The principal complaints of oil spill clean-up workers participating in Deepwater Horizon (DWH) clean-up activity along the coast of Louisiana are illustrated in Figure 9 [D'Andrea, 2014, Figure 2].

An association between exposure to dispersants, specifically Corexit™ EC9527A or Corexit™ EC9500A, and adverse acute health effects (burning in the nose, throat, or lungs, tightness in chest, and burning eyes) during clean-up operations and in some case persisting 1 to 3 years later was reported [McGowan, 2017].[7]

Carcinogenicity

The risk of carcinogenesis due to crude oil exposure is a common concern among members of the public after a release. To date, there is no epidemiological evidence to link crude oil spill exposure to carcinogenic effects. Furthermore, the International Agency for Research on Cancer (IARC) has determined that there is "limited evidence for the carcinogenicity in experimental animals of crude oil" and "inadequate evidence for the carcinogenicity in humans of crude oil." IARC concludes that "crude oil is not classifiable as to its carcinogenicity to humans (Group 3)" [IARC, 1989].

However, some components of crude oil are carcinogenic or possibly carcinogenic (see CDC, 2010a for a listing of hazardous components found in light crude oil).

Benzene has been considered a possible carcinogen by IARC since 1979 based on a suggested relationship between benzene exposure and leukaemia (predominantly myelogenous leukaemia) [IARC, 1979]. Benzene was classified as a Group-I carcinogen, by IARC in 1987 citing additional evidence of acute nonlymphocytic leukemia in workers exposed to benzene [IARC, 1987]. In 2017 IARC confirmed the carcinogenicity to humans on the basis of sufficient evidence in humans, sufficient evidence in experimental animals, and strong mechanistic evidence. In adult humans, benzene causes acute non-lymphocytic leukaemia, including acute myeloid leukaemia. Previous observations of limited evidence for chronic lymphocytic leukaemia, multiple myeloma, and non-Hodgkin lymphoma were also confirmed. Positive associations with exposure to benzene were also observed for chronic myeloid leukaemia and for lung cancer in several studies [Loomis, 2017].

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[6] Braer, 1993; Sea Empress, 1996; Nakhodka, 1997; Prestige, 2002; Tasman Spirit, 2003; Hebi Spirit, 2007; oil company pipeline, 2000.

[7] Corexit is produced by Nalco/Exxon Energy Chemicals. The MDS for COREXIT R A lists 2-butoxyethanol (CAS 111-76-2), proprietary organic sulfonic acid salt and propylene glycol (CAS 57-55-6) as hazardous subtances [Nalco, 2014]. ATSDR (2010a) discussed personal protective requirements, potential health effects, and treatment for persons handling or transporting Corexit during the cleanup of the DHW oil spill.

Ethylbenzene has been evaluated as a Group 2B carcinogen (possibly carcinogenic to humans) based on the findings that there is inadequate evidence in humans for carcinogenicity but sufficient evidence in experimental animals [IARC, 2000; ATSDR, 2010b].

Toluene has been categorized by IARC as Group 3 (not classifiable as to its carcinogenicity in humans) with a supporting statement that there is inadequate evidence in humans and that available evidence suggest a lack of carcinogenicity of toluene in experimental animals [IARC, 1999; EPA, 2005].

Xylenes have also been categorized by IARC as Group 3 [IARC, 1999; ATSDR, 2007].

Of the PAHs found in crude oil, **benzo[a]pyrene** is carcinogenic to humans (Group 1) [IARC, 2010] (see IARC 2010 for discussion of other PAHs).

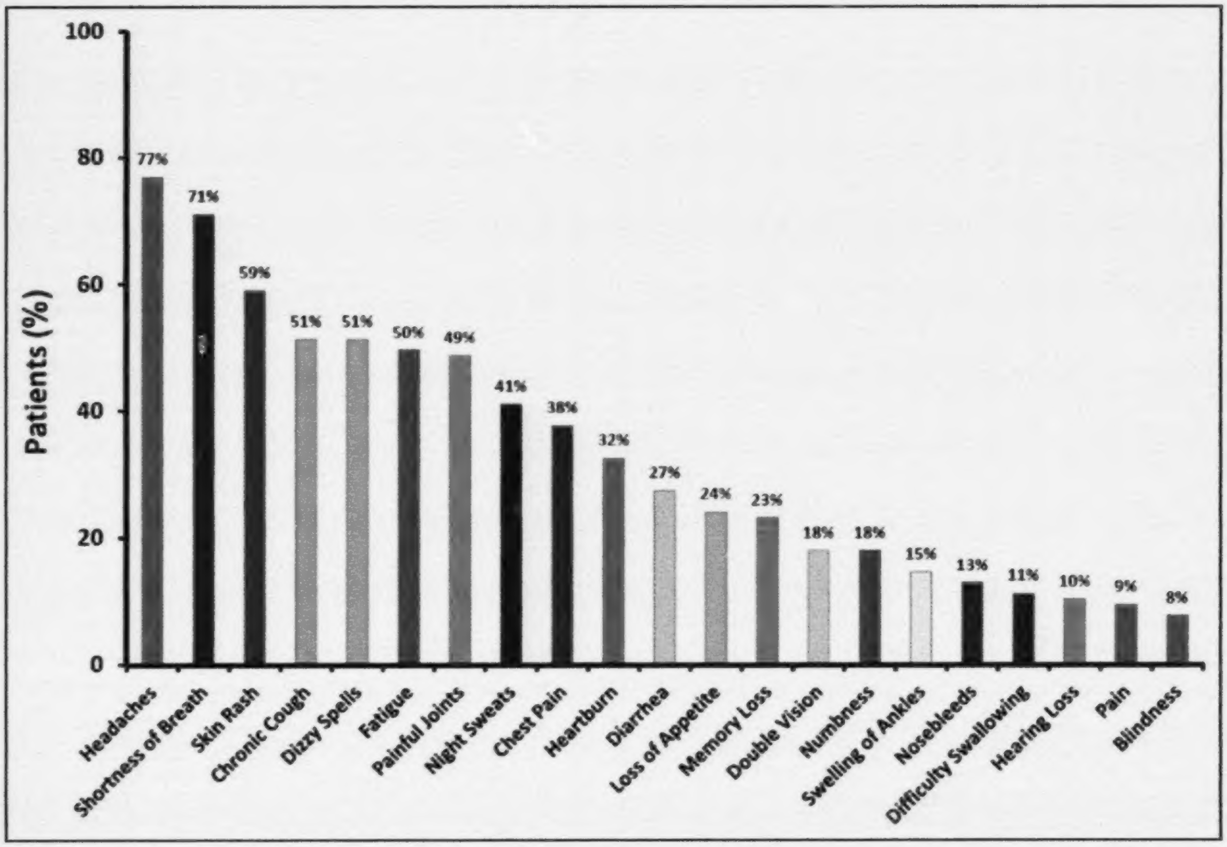

Figure 9: Major symptoms experienced by oil spill clean-up workers engaged in the Deepwater Horizon clean up along the coast of Louisiana following exposure to oil spill and dispersant

Toxicology of burning oil

Burning crude oil generally produces heat and dense clouds of thick black smoke. The smoke is composed of solid unburned carbon (soot) and other "particulate" pollutants (in both the solid and liquid states), as well as gases of volatile substances and vaporized matter.

The chemical pollutants found in the smoke vary with the composition of the crude oil and factors related to how it is burned. There are several combustion products that may be present and could be significant health hazards. These products include non-carbon substances (like acids and metals) as additional free particles or stuck to the surface of the soot; gases (like carbon dioxide, carbon monoxide, sulfur oxides, nitrogen oxides, and hydrogen sulfide); and vaporized liquids and solids.

Generally, the harmful substances decrease with distance from fire and smoke [Barnea, 2017; CB&I, 2015].

Box 1: What are particulate matters?

PM is a complex mixture of extremely small particles and liquid droplets made up of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

PM is separated into two groups: inhalable coarse particles (aerodynamic diameter <10 µm; PM_{10}) and fine particles ($PM_{2.5}$).

PM_{10} is often found near roadways and dusty industries, whereas $PM_{2.5}$ particles are emitted from fires or can form when gases released from industrial sources and fossil fuel combustion react in the air.

Adverse health effects attributed to short-term exposure to $PM_{2.5}$ include non-fatal heart attacks, aggravated asthma, and impaired lung function

[Nance, 2015; EPA, 2017]

2.3.3 Mental health

Psychological and behavioural effects have been reported in clean-up workers and in the exposed population following major oil spills (see Annex F: Epidemiological studies on mental health effects related to exposure to oil spills). Adverse effects include higher rates of mental distress, an inability to concentrate, memory loss, anxiety, depression and post-traumatic stress disorder (PTSD) [Palinkas, 1993; Lyons, 1999; Rung, 2016; Jung, 2017; Généreux, 2015].

For residents who (1) suffered high levels of clinically significant anxiety and depression and (2) lived in coastal communities affected by the Deepwater Horizon (DHW) oil spill, income loss rather than direct contact with the oil was the most significant driver of the psychological effects [Morris, 2013].

It has been suggested that the resources mobilized to reduce the economic and behavioural health impacts on the DHW spill on coastal residents (including compensation for lost income from British Petroleum and increases in available mental health services) may have resulted in a reduction in potential health problem [Gould, 2014].

2.3.4 Community Impacts

Epidemiological research from past disasters has provided insight regarding the extent to which crude oil releases may impact entire communities. These impacts include concerns over **food safety and livelihoods** [Palinkas, 1993; Goodlad, 1996].

In addition, **social disruption** (e.g., breakdown of family and social structures) was reported following the *Exxon Valdez* oil spill [Picou, 1992; Arata, 2000]. After both the *Exxon Valdez* and DWH oil spills, higher rates of domestic conflict among exposed subjects and their partners were reported [Palinkas, 1993; Rung, 2016].

Crude oil releases have also been implicated in **cultural erosion**, which occurs when traditional activities or practices can no longer occur (e.g., destruction of a cultural site, loss of a traditional food). Communities may be impacted by **litigation stress**, which broadly refers to anxiety, conflict, and/or dissatisfaction that arises from having to seek compensation through legal means [Picou, 2004; Mayer, 2015].

2.4 Which populations are of particular concern in the aftermath of a crude oil spill?

Clean-up workers (professional and volunteer) are expected to have the greatest risk of acute physical impacts due to direct exposure to spilled oil, particularly if PPE is used incorrectly [Gwack, 2012; Suarez, 2005]. Much less is known regarding acute physical impacts in the general population, although it should be noted that this group includes more vulnerable individuals, such as the elderly, pregnant women, and the chronically ill, compared to the relatively healthy clean-up worker population. However, as reviewed in Sections 2.3.3 and 2.3.4, the general population may experience mental health and community impacts, even without direct contact with spilled oil.

Box 2: Why do children require special care during disasters?

Children require special care during disaster because:

- They are physiologically more vulnerable to toxic exposures;
- They are developmentally less able to communicate concerns or medical needs;
- They are psychologically less capable of interpreting events or coping with stress; and
- Psychological trauma is more likely to impact long-term well-being.

Children should be supported by:

- Ensuring immediate family reunification, if separated;
- Limiting exposure to news media, as they may misinterpret looping coverage as an ongoing or repeated event; and
- Resumption of normal activities as soon as possible and creating child-friendly spaces and opportunities for age-appropriate play with peers in emergency situations.

[CDC, 2017a]

Children comprise a second population of concern. Effects on children's health are discussed in detail in reports by Abramson, 2010; Murray, 2013; Osofsky, 2016; U.S. Institute of Medicine, 2010 (see Annex E: Epidemiological studies on physical/physiological effects experienced by humans exposed to oil spills and Annex F: Epidemiological studies on mental health effects related to exposure to oil spills). General considerations for protecting children during disasters are summarized in Box 2.

Box 3: Why are indigenous communities differentially impacted by disasters?

First Nations or indigenous communities may be disproportionately impacted by crude oil spills in their traditional territories as a result of several factors, including:

- ***Logistical difficulties*** in providing emergency services to remote or isolated communities;
- ***Variability in administrative and technical capacity*** that may hinder participation in response and recovery;
- ***Lack of trust***, a legacy of colonialism, that may affect coordination or collaboration during the response, and which may impact the utilization of health services;
- ***Deep reliance on local ecosystems*** for food and other resources necessary for economic, socio-cultural, spiritual, and physical well-being; and
- The existence of profound ***social and health inequities*** that may leave Indigenous communities more vulnerable to mental or physical health impacts, and/or less able to respond.

[Eykelbosh, 2018]

There are a number of factors that may make **Indigenous communities** more susceptible to the negative impacts of a crude oil release (see Box 3). During and after the *Exxon Valdez* oil spill in Prince William Sound, AK, a number of studies examined impacts on Indigenous communities compared to non-Indigenous residents. Among Indigenous Alaskans, depression scores were significantly associated with having participated in clean-up and having experienced impacts on hunting, fishing, and gathering activities; these impacts were more severe among women [Palinkas, 1992]. Finally, Indigenous communities experienced a number of the broader impacts mentioned in Section 2.3.4, including social disruption [Palinkas, 1993; Palinkas, 2004], litigation stress [Picou, 2004], and cultural erosion [Dyer, 1993].

2.5 What are the health protection standards and guidelines for assessing the health risks from crude oil exposure?

Several agencies in Canada and the United States have provided reference values for acute exposure to VOCs, PAHs, and heavy metals found in crude oil and for additional chemicals and particulate matter (PM) resulting from the combustion of crude oil. Exposure guideline values for the main chemicals of health concern for air and drinking water quality are discussed below. Soil contamination considerations are beyond the scope of this document.[8]

2.5.1 Air quality

Crude oil is classified as a chemical substance of unknown or variable composition (see Section 1.1). Air emissions from a crude oil spill may include VOCs (e.g., alkanes, benzene, toluene, ethylbenzene, xylenes), PAHs, and hydrogen sulfide [CDC, 2010a]. When oil is burned, atmospheric emissions of concern include particulate matter precipitating from the smoke plume, combustion gases, unburned hydrocarbons, and organic compounds.

Health Canada (HC) and most United States government agencies consider Acute Exposure Guidelines Levels (**AEGLs**) [EPA, 2016a] to be the preferred value for the assessment of acute exposure situations.

A list of 471 chemicals were identified as high priority in the AEGL program[9]; final AEGLs were determined for 176, interim AEGLs for 84, and proposed AEGLs for 12 [EPA, 2016a].

If AEGLs are not available, Emergency Response Planning Guidelines (**ERPGs**) [NOAA, 2018] would be the second choice and Temporary Emergency Exposure Levels (TEELs) [DOE, 2016] the third choice.

In the absence of these reference values, National Ambient Air Quality Standards (**NAAQS**), set by the EPA for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment [EPA, 2016b], or Canadian Ambient Air Quality Standards (**CAAQS**), determined for particulate matter, ozone and sulfur dioxide [CAAQS, 2014], could be considered. Since AEGLs, ERPGs, and TEELs have not been determined for particulate matter, NAAQS or CAAQS could be used. AEGLs, ERPGs, and TEELs values for the main VOCs and PAHs that are released into the air during a crude oil spill are given in Table 12 and in Table 13.

AEGLs, ERPGs, TEELS, NAAQs, and CAAQS for hydrogen sulfide and the main gaseous pollutants that are released into air from a burning crude oil spill are given in Table 14.

Box 4 describes reference values for acute exposures to air pollutants that can be used to assess the risk to human health.

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[8] For guidance on federal contaminated site, see https://www.canada.ca/en/health-canada/services/environmental-workplace-health/contaminated-sites/guidance-documents.html

[9] See EPA, 2001 for a discussion of the Standing Operating Procedures for Developing AEGLs.

Box 4: What are the reference values for assessing health risks from acute exposure to air pollutants?

Several reference values can be used to assess the risk to human health from acute exposures to air pollutants. The recommended hierarchy of values is the same as that used by the U.S. Department of Energy (DOE) in formulating Protective Action Criteria (PACs) [DOE, 2016].

ute Exposure Guideline Level (AEGL) values published by the U.S. EPA [EPA, 2016a].

nergency Response Planning Guideline (ERPG) values produced by the American Industrial Hygiene Association
HA) [NOAA, 2018].

nporary Emergency Exposure Limit (TEEL) values developed by DOE Subcommittee on Consequence Assessment
d Protective Actions [DOE, 2016].

AEGLs, developed by the National Advisory Committee for the development of AEGLs for Hazardous Substances, represent threshold exposure limits for the general public (including infants, children, and other individuals who may be susceptible) and are applicable to emergency exposure periods ranging from 10 minutes to 8 hours (10 and 30 minutes; 1, 4, and 8 hours). Three AEGLs are defined:

- **AEGL-1** is the airborne concentration (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
- **AEGL-2** is the airborne concentration (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL-3** is the airborne concentration, (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

ERPGs were developed by the AIHA Guideline Foundation's Emergency Response Planning (ERP) Committee to assist emergency response personnel in planning for catastrophic chemical releases to the community. ERPGs provide guideline levels for once-in-a-lifetime, short-term (typically 1-hour) exposures to airborne concentrations of acutely toxic, high-priority chemicals and are applicable to most individuals in the public. Three ERPGs are defined:

- **ERPG-1:** Maximum airborne concentration (ppm) below which nearly all individuals could be exposed for up to one hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odour.
- **ERPG-2:** Maximum airborne concentration (ppm) maximum airborne concentration below which nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.
- **ERPG-3:** Maximum airborne concentration (ppm) maximum airborne concentration below which nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

TEELs were developed by DOE for chemicals lacking AEGLs or ERPGs so that DOE facilities could conduct Emergency Planning Hazard Assessments and consequence assessments during responses. TEELs pertain to nearly all individuals and are based on concentration limits or toxicology parameters. Three TEELs are defined:

- **TEEL-1:** Airborne concentration (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure.
- **TEEL-2:** Airborne concentration (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience irreversible or other serious, long-lasting, adverse health effects or an impaired ability to escape.
- **TEEL-3:** Airborne concentration (ppm or mg/m^3) of a substance above which it is predicted that the general population, including susceptible individuals, when exposed for more than one hour, could experience life-threatening adverse health effects or death.

Table 12: AEGLS and ERPGs values for the main VOCs released into the air during a crude oil spill

Substance	Time	AEGL-1	AEGL-2	AEGL-3	ERPG-1	ERPG-2	ERPG-3
Benzene (ppm) (CAS RN 71-43-2) Note: Interim value [EPA, 2016a]	10 min	130	2000*				
	30 min	73	1100	5600*			
	60 min	52	800	4000*	50	150	1000
	4 hrs	18	400	2000*			
	8 hrs	9	200	990			
	Lower Explosive Limit (LEL) = 14,000 ppm; * = >10% LEL; ** = >50% LEL AEGL 3 – 10 mins = ** 9,700 ppm For values denoted as * safety considerations against the hazard(s) of explosion(s) must be taken into account; for values denoted as ** extreme safety considerations against the hazard(s) of explosion(s) must be taken into account. Conversion factor: 1 ppm = 3.24 mg/m³						
Ethylbenzene (ppm) (CAS RN 100-41-4) Note: Interim value [EPA, 2016a]	10 min	33	2900	4700			
	30 min	33	1600	2600			
	60 min	33	1100	1800			
	4 hrs	33	660	1000			
	8 hrs	33	580	910			
	Conversion factor: 1 ppm = 4.35 mg/m³						
Toluene (ppm) (CAS RN 108-88-3) [EPA, 2016a]	10 min	67	1400*	10000**			
	30 min	67	760	5200*			
	60 min	67	560	3700*	50	300	1000
	4 hrs	67	310	1800*			
	8 hrs	67	250	1400*			
	Lower Explosive Limit (LEL) = 14,000 ppm; * = > 10% LEL; ** = > 50% LEL AEGL 3 – 10 min = **10,000 ppm For values denoted as * safety considerations against the hazard(s) of explosion(s) must be taken into account; for values denoted as ** extreme safety considerations against the hazard(s) of explosion(s) must be taken into account. Conversion factor: 1 ppm = 3.77 mg/m³						
Xylene (ppm) (CAS RN 1330-20-7) [EPA, 2016a]	10 min	130	2500*	7200**			
	30 min	130	1300*	3600*			
	60 min	130	920*	2500*			
	4 hrs	130	500	1300*			
	8 hrs	130	400	1000*			
	Lower Explosive Limit (LEL) = 9,000 ppm; * = >10% LEL; ** = >50% LEL For values denoted as * safety considerations against the hazard(s) of explosion(s) must be taken into account; for values denoted as ** extreme safety considerations against the hazard(s) of explosion(s) must be taken into account. Conversion factor: 1 ppm = 4.34 mg/m³						

Table 13: TEEL values for the main PAHs released into the air during a crude oil spill

Substance	Time	TEEL-1	TEEL-2	TEEL-3
Acenaphthene (mg/m³) (CAS RN 83-32-9)	60 min	3.6	40	240
Acenaphthylene (mg/m³) (CAS RN 208-96-8)	60 min	10	110	660
Anthracene (mg/m³) (CAS RN 120-12-7)	60 min	48	530	3200
Benzo(a)anthracene (mg/m³) (CAS RN 56-55-3)	60 min	0.6	120	700
Benzo(a)pyrene (mg/m³) (CAS RN 50-32-8)	60 min	0.6	120	700
Benzo(k)fluoranthene (mg/m³) (CAS RN 207-08-9)	60 min	0.019	0.2	1.2
Benzo(ghi)perylene (mg/m³) (CAS RN 191-24-2)	60 min	30	330	2000
Chrysene (mg/m³) (CAS RN 218-01-9)	60 min	0.6	12	69
Dibenz(a,h)anthracene (mg/m³) (CAS 53-770-3)	60 min	0.093	1	2.9
Fluoranthene (mg/m³) (CAS RN 206-44-0)	60 min	8.2	90	400
Fluorene, 9H- (mg/m³) (CAS RN 86-73-7)	60 min	6.6	72	430
Naphthalene (mg/m³) (CAS RN 91-20-3)	60 min	79	430	2,600
[DOE, 2016]				

Table 14: AEGLs, ERPGs, TEELs, NAAQS, and CAAQS values for hydrogen sulfide, and the main gaseous pollutants released into air from a burning crude oil spill

Substance	Time	AEGL-1	AEGL-2	AEGL-3	ERPG-1	ERPG-2	ERPG-3	TEEL-1	TEEL-2	TEEL-3	NAAQS	CAAQS
Hydrogen sulfide (ppm) (CAS RN 7783-06-4) [EPA, 2016a]	10 min	0.75	41	76								
	30 min	0.60	32	59								
	60 min	0.51	27	50	0.1	30	100					
	4 hrs	0.36	20	37								
	8 hrs	0.33	17	31								
	Conversion factor: 1 ppm = 1.4 mg/m^3											
If combustion occurs, others are:												
Sulphur dioxide(ppm) (CAS RN 7446-09-5) [EPA, 2016a]	10 min	0.2	0.75	30								
	30 min	0.2	0.75	30								
	60 min	0.2	0.75	30	0.3	3	25				0.075	
	4 hrs	0.2	0.75	19								
	8 hrs	0.2	0.75	9.6								
	Conversion factor: 1 ppm = 2.6 mg/m^3 [EPA, 2016a] Note: a CAAQS for one hour of 70 ppb will be effective in 2020 and 65 ppb in 2025											
Carbon monoxide (ppm) (CAS RN 630-08-0) [EPA, 2016a]	10 min	NR	420	1700								
	30 min	NR	150	600								
	60 min	NR	83	330	200	350	500				35	
	4 hrs	NR	33	150								
	8 hrs	NR	27	130							9	
	N.R. not recommended because susceptible persons may experience more serious effects (equivalent to AEGL-2) at concentrations that do not yet cause AEGL-1 effects in the general population. Conversion factor: 1 ppm = 1.145 mg/m^3											

Table 14: AEGLs, ERPGs, TEELs, NAAQS, and CAAQS values for hydrogen sulfide, and the main gaseous pollutants released into air from a burning crude oil spill (cont'd)

Substance	Time	AEGL-1	AEGL-2	AEGL-3	ERPG-1	ERPG-2	ERPG-3	TEEL-1	TEEL-2	TEEL-3	NAAQS	CAAQS
Ozone (ppm) (CAS RN 10028-15-6)	60 min							0.091	1	10		
	8 hrs										0.075	0.063*
	* CAAQS for one hour changes to 0.062 ppm in 2020											
Nitrogen dioxide (ppm) (CAS RN 10544-72-6) [EPA, 2016a]	10 min	0.50	20	34								
	30 min	0.50	15	25								
	60 min	0.50	12	20	1	15	30				0.1	
	4 hrs	0.50	8.2	14								
	8 hrs	0.50	6.7	11								
	Conversion factor: 1 ppm = 3.70 mg/m³											
Particle Pollution												
PM10 (μg/m³)	24 hrs										150	
PM2.5 (μg/m³)	24 hrs										35	28*
	*CAAQS will change to 27 μg/m³ in 2020											
Heavy metals												
Nickel (mg/m³)								4.5	50	99		
Cadmium (mg/m³) (CAS RN 7440-43-9) Note: Interim value [EPA, 2016a]	10 min	0.13	1.4	8.5								
	30 min	0.13	0.96	5.9								
	60 min	0.10	0.76	4.7								
	4 hrs	0.063	0.40	1.9								
	8 hrs	0.041	0.20	0.93								

Table 14: AEGLs, ERPGs, TEELs, NAAQS, and CAAQS values for hydrogen sulfide, and the main gaseous pollutants released into air from a burning crude oil spill (cont'd)

Substance	Time	AEGL-1	AEGL-2	AEGL-3	ERPG-1	ERPG-2	ERPG-3	TEEL-1	TEEL-2	TEEL-3	NAAQS	CAAQS
Mercury vapour (mg/m^3) (CAS RN 7439-97-6) Note: Interim value [EPA, 2016a]	10 min	NR	3.1	16								
	30 min	NR	2.1	11								
	60 min	NR	1.7	8.9				0.15				
	4 hrs	NR	0.67	2.2								
	8 hrs	NR	0.33	2.2								
Vanadium (mg/m^3)								3	5.8	35		

2.5.2 Drinking water quality

The crude oil components benzene, ethylbenzene, toluene, and xylenes (BTEX) and benzo[a]pyrene are of particular concern in drinking water. Health Canada and the Federal-Provincial-Territorial Committee on Drinking Water [HC, 2017] has established a maximum acceptable concentration (MAC) for these chemicals along with aesthetic objectives (see Box 5 and Table 15).

Additional information on the application of these values and how they were derived can be found in the respective Guideline Technical Documents (HC 2009; HC, 2015).

Table 15: Minimum acceptable concentrations of BTEX and benzo[a]pyrene in drinking water

Chemical	MAC (mg/L)	Aesthetic objective (mg/L)
Benzene	0.005	na
Ethylbenzene	0.14	0.0016
Toluene	0.06	0.024
Xylenes	0.09	0.02
benzo[a]pyrene	0.000 04	na

Specific guidance related to the implementation of drinking water guidelines should be obtained from the appropriate drinking water authority in the affected jurisdiction as that jurisdictions may establish more stringent limits than the MAC.

In addition, where volatile contaminants are concerned, particular attention should be paid to the possibility of groundwater contamination.

Often, the occasional small, short-term exceedance of a MAC is not a significant concern to health. However, the magnitude of the exceedance and of the contaminant(s) in question must be considered.

The **World Health Organization** [WHO, 2006] notes that in assessing the significance of an exceedance of a guideline value, account should be taken of:

- Information underpinning the guideline value derivation;
- Local exposure to the substance of concern through other routes (e.g., food; inhalation);
- Any sensitive subpopulations; and
- Locally relevant protective measures to prevent the chemical from entering the source water or supply in the case of a spill.

Box 5: What are the maximum acceptable concentration (MAC) and aesthetic objective for a chemical in drinking water?

The maximum acceptable concentration (MAC) for a chemical in drinking water is:

- A guideline for exposure to a chemical, which is typically based on lifetime exposure (70 years) in the case of carcinogens;
- Considered protective of both cancer and non-cancer endpoints; and
- Measurable and achievable by both municipal- and residential-scale treatment technologies.

Aesthetic objective for a chemical in drinking water is:

- Established when a chemical can be detected by its odour, taste, and/or visual appearance;
- Is not based on health considerations, but does not preclude the possibility that a health-based value or MAC has also been established for the compound; and
- Can be a lower value than the corresponding MAC.

Section 3. PUBLIC HEALTH RISK MANAGEMENT

In Canada, public health is a responsibility that is shared by the three levels of government in collaboration with the private sector, non-governmental organizations, health professionals, and the public. This joint responsibility is further extended when examining the professional disciplines involved with the management of industrial chemicals across their life cycles. Thus, a multi-disciplinary and multi-sectoral approach across each phase of the emergency management continuum (i.e., prevention, preparedness, response, and recovery) is required to manage the population health and environmental risks resulting from major chemical incidents, including for significant crude oil releases.

Section three is divided into three sub-sections and provides several practical checklists (decision aids) designed to be easily consulted and printed independently. They are not meant to be exhaustive.

The first subsection provides general information on prevention and preparedness activities that public health practitioners can undertake to better prepare their community or area of jurisdiction for the risk of a crude oil release.

The second subsection provides more detailed guidance and lists resources available to support a public health response to a major release of crude oil. It also describes management of the incident, including sheltering-in-place versus evacuation decisions, human decontamination, and crisis communications.

The third subsection describes recovery and epidemiological follow-up considerations.

3.1 What activities can public health practitioners undertake to better prepare their community for the risk of a crude oil release?

Public health practitioners can support local and national initiatives on the safe use of hazardous chemicals, including crude oil, and the reduction in their use through activities such as those listed in Checklist 1.

Checklist 1: Proposed activities to better prepare communities to the risk of a crude oil release

- ☐ Determine if crude oil is transported by rail through your community and, if it is, support requirements that local Emergency Medical Service (EMS) and Hazardous Materials (HazMat) personnel be provided with a schedule of regular shipments.
- ☐ Determine if crude oil pipelines pass through or near your community.
- ☐ Contribute to land use planning and zoning regulations to keep critical infrastructure, (i.e., hospitals, health care facilities, long-term care facilities, schools, water intakes, public water supplies, groundwater recharge zones, and emergency alternative community water supplies), vulnerable populations, and residential areas well away from oil refineries, rail lines, and pipelines.
- ☐ Support initiatives to prohibit the rail or road transportation of hazardous material through populated areas (e.g., designation or construction of hazardous material routes around populated areas).
- ☐ Ensure that local EMS and HazMat personnel are trained and equipped to deal with crude oil emergencies.
- ☐ Ensure that the local/regional hospitals have a response plan and resources to deal with crude oil emergencies.
- ☐ Maintain an inventory of medical assets, roster of experts, and laboratories.
- ☐ Ensure that all communities have an emergency management and response plan in place (including designated evacuation routes and emergency shelters) and that it is regularly updated and exercised.
- ☐ Participate in community awareness, education messages, and emergency response exercises.
- ☐ Have a plan in place to deal with volunteers from the community, who will require additional training and monitoring if they wish to assist in clean-up operations after an oil spill, as well as community representatives who have a legitimate reason to be present at the site.
- ☐ Have a questionnaire on exposure and health status readily available for distribution to persons who were exposed or believe they were exposed during the incident. This should include the collection of contact information for follow-up (if necessary). Information should be provided regarding how the data will be stored, shared, and used.
- ☐ Develop coordination and collaboration mechanisms with key response stakeholders.
- ☐ Contribute to the development of policies, legislation, guidance, and plans regarding crude oil transportation and use.
- ☐ Build capacity and establish working systems for detecting, alerting, and responding to crude oil release.
- ☐ Maintain an inventory of institutions that have the technical expertise and equipment to monitor oil spills (in air, water, and soil) and to analyze the resultant data. Establish working relationships with these groups.
- ☐ Develop public health risk messaging aimed at both the public and local health care providers.

3.2 What actions should to be taken if a sudden major crude oil release occurs?

Notifying incident response authorities and initiating the Incident Command System (see Box 6) are typically the first activities carried out by first responders. Public Health authorities may also need to conduct a rapid health risk assessment. These activities may be supported by other specialized resources participating in the incident command team, including industry experts who provide detailed technical and operations expertise and carry out hazmat response and remediation operations.

This subsection contains the following decision aids[10]:

- Checklist 2: Health-related concerns in the event of a major crude oil release
- Checklist 3: Typical local hazmat response activities undertaken by first responders
- Checklist 4: Considerations for conducting a rapid population health risk assessment
- Checklist 5: Comprehensive resources to inform a response to hazmat incidents
- Checklist 6: Specialized medical and toxicological resources to inform a response to hazmat incidents
- Checklist 7: Evacuations vs sheltering-in-place considerations
- Checklist 8: Human decontamination and treatment considerations
- Checklist 9: Data to be collected from participants in follow-up studies

Additional guidance on responding to pipeline incidents, derailments and marine incidents is given in Annex G: Guidance on onsite response to pipeline incidents, derailments and marine incidents.

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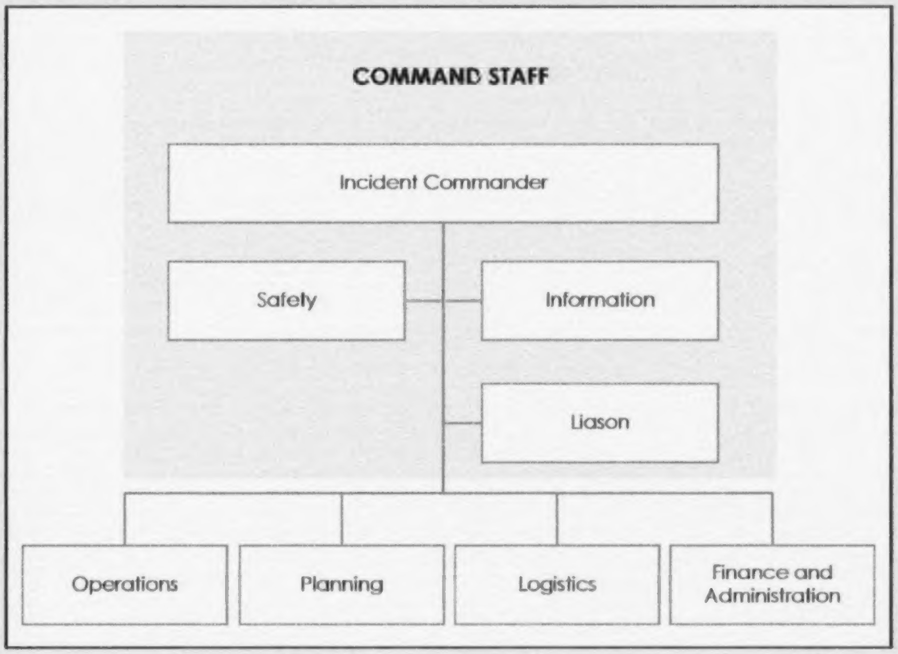
[10] The checklists are not meant to exhaustive and proposed activities may not be listed in priority sequence.

Box 6: What is the Incident Command System (ICS)?

The Incident Command System (ICS) provides a standardized, on-scene and off-scene, all-hazard incident management concept designed to enable effective and efficient incident management by integrating a combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure. It allows management teams to adopt an integrated organizational structure to match the complexities and demands of single or multiple incidents involving multiple agencies and includes all the personnel at the scene of an incident, such as first responders, public health personnel, emergency planners, personnel from environmental agencies, and toxicologists [WHO, 2009; FEMA, 2017; OSHA, 2005]. The ICS structure is recommended by the United Nations [WHO, 2009] and is used in many countries, including Canada, the United States, and the United Kingdom.

The ICS is normally structured to facilitate activities in five major functional areas: command, operations, planning, logistics, and finance and administration. A typical ICS structure is shown below [OSHA, 2005; BCERMS, 2015; KMC, 2016]:



When responding to an emergency situation, the ICS sets objectives based on the following priorities [WHO, 2009]:

1. **life saving;**
2. **incident stabilization; and**
3. **property preservation.**

ICS training is provided by Canadian institutions [NAIT, 2017, JIBC, 2016] and through online courses [FEMA, 2017a; FEMA, 2017b; OSHA, 2018]

Checklist 2: Health-related concerns in the event of a major crude oil release

Public and vulnerable populations	☐ Am I at risk of developing adverse health effects? ☐ Are my children (and pets) at risk? ☐ What are the health effects? Can I expect delayed effects? ☐ What should I do to reduce the risk of chemical exposure? ☐ Can I drink water and eat local foodstuff? ☐ What should I do if I or my family experience symptoms? ☐ How should I safely clean or dispose of oil-contaminated items?
Emergency responders	☐ Is there a risk of explosion or fire? ☐ What Personal Protective Equipment (PPE) is required? (see Annex H) ☐ What chemicals are involved? What is their identity? ☐ What are their toxicological properties? ☐ How do I decontaminate?
Medical professionals	☐ What are the typical signs and symptoms from exposure to the chemical(s)? ☐ How do I treat? ☐ Where are analyses of human samples for diagnoses and treatment done? ☐ What PPE is required? ☐ How and where is decontamination carried out?

Public health authorities, decision-makers and elected officials	☐ What protective actions, such as evacuation or shelter-in-place, should be communicated/ordered to minimize exposure to health hazards?
	☐ What safety advice should be given to the public regarding air quality, drinking water and food consumption, showering/bathing, recreational swimming, etc.?
	☐ Is there a need to develop and implement an environmental monitoring plan to inform decisions?
	☐ If communities were evacuated:
	    ☐ When can people safely return home and use public spaces?
	    ☐ What tests or checks must be performed to ensure that a home or public space is safe for re-occupancy?
	    ☐ Is sufficient environmental monitoring data available to support the conclusion that the affected area is safe to live in?
	☐ Are essential services operational?
	☐ How are damaged food and oiled possessions safely disposed of?
	☐ What remediation or restoration measures should be implemented?
	☐ Should a registry of exposed populations (public, workers and clean-up workers) be created?
	☐ Should longer-term environmental and/or epidemiological studies be conducted?

Checklist 3: Typical local hazmat response activities undertaken by first responders

- ☐ Notifying and seeking technical support from the Canadian Transport Emergency Centre (**CANUTEC**) (613-996-6666 or *666 on a cellular phone).
- ☐ Alerting and notifying applicable local, regional, provincial and territorial authorities, the public, hospitals, environmental public health authorities and federal regulatory authorities:
  - ☐ **Pipeline emergencies**: the **Transportation Safety Board** (TSB) (1-800-387-3557) and the pipeline company.
  - ☐ **Rail emergencies**: the **Transportation Safety Board** (TSB) see (http://www.tsb.gc.ca/eng/incidents-occurrence/rail/index.asp) for regional number and the railway company.
  - ☐ **Marine incidents:** the Canadian Coast Guard (CCG) (see http://www.ccg-gcc.gc.ca/eng/CCG/ER_Reporting_Incident), (1-800-387-3557) and the shipping company.
- ☐ Securing and managing the site.
- ☐ Setting-up an **incident command system** (see Box 6).
- ☐ Establishing an initial chemical incident zoning plan (see Annex G: Guidance on onsite response to pipeline incidents, derailments and marine incidents)

Supported by public health authorities, industrial hygienists, occupational health and safety professionals as well as regulatory authorities:

- ☐ Assessing the hazards and risks, with timely environmental sampling, monitoring, detection, analysis and dispersion modeling conducted by competent authorities, as required/possible.
- ☐ Accessing reach-back support (see Checklist 5 and Checklist 6).
- ☐ Executing actions - under the leadership of the Incident Commander - to minimize exposure and protect populations, such as:
  - ☐ On-scene decontamination and victims triage [see Checklist 8];
  - ☐ Ensuring timely access to and administration of adequate medical and ventilation resources;
  - ☐ Deciding whether to shelter-in-place or to evacuate (see Checklist 7); and
  - ☐ Issuing health advisories (e.g., Air Quality Advisories, Do not Drink Water Advisories, Do not Consume Advisories, Do not Use Advisories (recreational waters), Fisheries Closures, Shelter-in-Place).

Checklist 4: Considerations for conducting a rapid population health risk assessment

Conduct a preliminary assessment:

☐ What has happened?
☐ What chemicals were or could be released?
☐ What are the hazards?
☐ Who are/might be exposed and through what routes?
☐ What are the symptoms and health effects if exposed?
☐ Who and where are the vulnerable populations?
☐ What can be done to minimize harm?
☐ What are the existing response capabilities?
☐ Are there any critical knowledge gaps?

Consider expanding the assessment

☐ Gather health and environmental data
☐ Measure/estimate hazard transport and fate with support from competent agencies (see Checklist 5)

Characterize risk based on best currently available information

Contribute to the development of risk and crisis communication messages

Checklist 5: Comprehensive resources to inform a response to hazmat incidents

☐ **WISER** Wireless Information System for Emergency Responders system. Designed to assist emergency responders in hazardous material incidents (substance identification support, physical characteristics, human health information, containment, and suppression advice) [https://www.wiser.nlm.nih.gov].
☐ **ERG2016** Emergency Response Guidebook. The ERG2016 is primarily a guide to aid first responders in quickly identifying the specific or generic hazards of the material(s) involved in the incident, and protecting themselves and the general public during the initial response phase of the incident. [https://www.tc.gc.ca/eng/canutec/guide-menu-227.htm].
☐ **CAMEO** (Computer-Aided Management of Emergency Operations) — system of software applications used to plan for and respond to chemical emergencies [https://www.epa.gov/cameo].
☐ **NIOSH** Pocket Guide to Chemical Hazards — information on workplace chemicals and their hazards [https://www.cdc.gov/niosh/npg/].
☐ Environmental Emergency Response Section (**EERS**), Canadian Meteorological Centre (CMC) (514-421-4614) for weather forecasting and modeling of release.
☐ Canadian Emergency Response Contractor's Alliance (**CERCA**) [http://www.cerca-aceiu.ca/]
☐ **International Program on Chemical Safety** [http://www.inchem.org/].
☐ U.S. Department of Health and Human Services, National Library of Medicine, **Disaster Information Research Center** [https://disaster.nlm.nih.gov/dimrc/chemicalemergencies.html].

Checklist 6: Specialized medical and toxicological resources to inform a response to hazmat incidents

Medical management	☐ **Poison Control Centres** [http://www.capcc.ca/en] for regional number. ☐ Chemical Hazards Emergency Medical Management (**CHEMM**) — Enable first responders, first receivers, other healthcare providers, and planners to plan for, respond to, recover from, and mitigate the effects of mass-casualty incidents involving chemicals [https://chemm.nlm.nih.gov/index.html] ☐ **Medical Management Guidelines for Acute Exposures** [https://www.atsdr.cdc.gov/MMG/index.asp]
Human Decontamination	☐ U.S. Department of Health and Human Services (DHHS) Chemical Hazards Emergency Medical Management **CHEMM Decontamination Procedures** [https://chemm.nlm.nih.gov/decontamination.htm] ☐ U.S. Department of Health and Human Services (DHHS /U.S. Department of Homeland Security (DHS) **Patient Decontamination in a Mass Chemical Exposure Incident: National Planning Guidance for Communities** [https://www.dhs.gov/sites/default/files/publications/Patient%20Decon%20National%20Planning%20Guidance_Final_December%202014.pdf]
Air quality	☐ U. S. Environmental Protection Agency (**EPA**): **Acute Exposure Guideline Levels (AEGLs) for airborne chemicals** [https://www.epa.gov/aegl]. ☐ U.S. Department of Energy **(DOE) Protective Action Criteria (PAC) with AEGLs, ERPGs, and TEELs:** Rev. 29' for Chemicals of Concern — [https://energy.gov/ehss/protective-action-criteria-pac-aegls-erpgs-teels-rev-29-chemicals-concern-may-2016]
Drinking water quality	☐ **Guidance for Issuing and Rescinding Drinking Water Avoidance Advisories in Emergency Situations** [https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-issuing-rescinding-drinking-water-avoidance-advisories-emergency-situations.html]
Toxicology and hazardous material properties	☐ US NIH – **NLM Toxnet** [https://toxnet.nlm.nih.gov/] includes the **Hazardous Substances Data Bank (HSDB)** which provides information on human exposure, industrial hygiene, emergency handling procedures, and environmental fate. [http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB]. ☐ **CDC Emergency Preparedness and Response** — information on specific chemical agents, case definitions, toxic syndrome description, toxicological profiles, emergency response cards [https://emergency.cdc.gov/chemical/] ☐ Agency for Toxic Substances and Disease Registry (ATSDR), **Toxicological Profiles** — detailed information about contaminants found at hazardous waste sites [https://www.atsdr.cdc.gov/toxprofiles/index.asp)
Epidemiogical toolkits	☐ **Assessment of Chemical Exposure (ACE) Toolkit** — surveys, consent forms, training materials, and Epi Info ™ 7 databases [https://www.atsdr.cdc.gov/ntsip/ace_toolkit.html] ☐ **Community Assessment for Public Health Emergency Response (CASPER)** — epidemiologic technique designed to provide quickly and at low-cost household based information about a community [https://www.cdc.gov/nceh/hsb/disaster/casper/default.htm] ☐ **Rapid Acquisition of Pre- and Post-Incident Disaster Data Study (RAPIDD Study)** — pre-positioned protocol intended to minimize the time needed to begin collecting health data and biological samples from disaster response workers who may be exposed to environmental contaminants. RAPIDD includes all the documents and procedures needed to create a registry of workers. [https://dr2.nlm.nih.gov/protocols#rapidd]

Training	☐ **ToxTutor** —tutorial covering key principles of toxicology [https://toxtutor.nlm.nih.gov/] ☐ U.S. National Institute of Environmental Health Sciences (NIEHS) health and safety guidance to those involved in disaster response and clean-up activities through [https://tools.niehs.nih.gov/wetp/index.cfm?id=2495#OilSpillResponseTrainingTool^ç] ☐ University of New Hampshire's (UNH) Coastal Response Research Center (2014) A Training Module: Dispersion Use Risk Communication Guidance and Tools. [http://crrc.unh.edu/sites/crrc.unh.edu/files/agency_training_module_risk_comm_dispersants_final_draft.pdf]

3.2.1 Evacuation and sheltering-in-place

Eliminating or minimizing exposure is of utmost importance to protect the health of a population located in the vicinity of any hazardous material release, including a major crude oil incident.

After any chemical release of public health concern, authorities are confronted with the difficult decision of whether to order evacuation or to shelter-in-place.

While mass evacuation may appear as the most appropriate public health protective action, evacuation is logistically challenging and, in many instances, may lead to situations that increase exposure, or risks of other types of harm, such as road accidents. **Public safety should be the over-riding priority.**

An evacuation should only be carried out if the benefit of leaving an area significantly outweighs the risk of sheltering-in-place [HMG, 2014]. The risk of both the exposure level and the exposure duration must be the primary consideration with the intrinsic risks of moving large numbers of people being a secondary consideration [WHO, 2009].

Shelter-in-place is define as taking "immediate shelter where you are — at home, work, school, or in between (e.g., in a vehicle)." [CDC, 2014a; CDC, 2017b].

However, every release has unique factors that influence the decision to evacuate or shelter-in-place (see Checklist 7). This decision should be left to the incident commander who can best assess the particular release in consultation with public health authorities.

Many local authorities, companies, businesses, schools and institutions have posted their specific shelter-in-place instructions on their websites (e.g., Emergency Management British Columbia, 2014; Regional District of Nanaimo, 2014; the City of Brandon, 2017 and the American Red Cross, 2014).

3.2.2 Medical countermeasures

Chemical antidote to treat casualties of crude oil exposure

There is no specific antidote to treat casualties of crude oil exposure.

Laboratory test to support diagnosis and treatment

There is no specific laboratory test to support diagnosis and treatment of crude oil exposure. Diagnostic testing should be based on clinical history.

Casualty decontamination and immediate treatment

Checklist 8 provides guidance on decontamination and immediate treatment.

Checklist 7: Evacuations vs sheltering-in-place considerations

Key considerations	☐ Did the release cause a fire or explosion or is fire or explosion possible? ☐ Is the release possible, ongoing, or over? ☐ If continuing, how quickly can the release be stopped? ☐ If possible, can measures be taken to significantly reduce the possibility of release? ☐ What are the physical properties of the hazardous material released? ☐ Does the material present a toxic, flammable, or explosive hazard or a combination of these? ☐ Did the release occur in a rural or urban area? ☐ How many people are affected? ☐ What shelters are available? ☐ Can the people be safely evacuated in time? ☐ What are the meteorological forecasts to estimate airborne contaminants dispersion to inform evacuation and sheltering decisions?
Evacuation is the better option over sheltering-in-place, if	☐ The risk of fire or explosion exists; ☐ Area is not yet exposed, but will be after a certain time (e.g., due to an anticipated shift in wind direction) when the time to exposure is longer than the time required for the evacuation; ☐ The likely duration of exposure is such that the protection offered by in-place sheltering may become insufficient; ☐ The chemicals are widely dispersed and contamination is extensive and persistent; ☐ The chemicals are suspected to be hazardous, but cannot be readily identified; ☐ The chemical is highly hazardous; ☐ The concentration in the air will be hazardous for a prolonged period; ☐ The number of evacuees is relatively small; ☐ Air quality monitoring indicates harmful levels of hazardous chemicals (hydrogen sulfide, volatile organic compounds, poly- aromatic hydrocarbons); and ☐ It will take some time to remediate soil contamination. [WHO, 2009, HMG 2014]
Public Instructions when sheltering in a building	☐ Shut and lock all doors and windows; ☐ Shut the heating, ventilating, and air conditioning (HVAC) system down; ☐ If there is danger of explosion, close window shades, blinds, or curtains; ☐ Take everyone, including pets, into an interior room with no or few windows and shut the door; ☐ Take essential disaster supplies (e.g., non-perishable food, bottled water, battery-powered radios) into the room; and ☐ Listen to your radio and other media (i.e., TV and social media) until the incident commander or the responsible authority tells you all is safe or orders you to evacuate. [CDC, 2014a; CDC, 2017b]

Checklist 8: Human decontamination and treatment considerations

Decontamination

- ☐ Casualties must be decontaminated before being transferred to a hospital/medical facility.
- ☐ Casualties can receive immediate life-saving treatment providing the responders are trained and equipped to provide the treatment without endangering themselves or further harming the casualty.
- ☐ Decontamination is necessary if the casualty requires oxygen or if a defibrillator is going to be used so that the possibility of accidental ignition is eliminated.
- ☐ Decontamination procedure:
    - ☐ Carefully remove all contaminated clothing. Clothing must NEVER be pulled over the head and should be cut off if necessary;
    - ☐ Wipe oil off the casualty, particularly from the head, neck, and trunk; and
    - ☐ Bag and label clothing as contaminated and stored outside [Lake, 2013; CDC, 2010b].

Treatment considerations

- ☐ **Seek medical attention if symptoms are evident or if exposure has or is suspected to have occurred**

For skin exposure:

- ☐ Wash the area with soap and water, baby oil, petroleum jelly, or a widely used, safe cleaning compound, such as the cleaning paste sold at auto parts stores.
- ☐ Avoid using solvents, gasoline, kerosene, diesel fuel, or similar products on the skin. These hydrocarbon-based products, when applied to skin, may present a greater health hazard than oil itself.

For eye (ocular) exposure:

- ☐ Immediately flush the eye with copious amounts of water for 15 minutes.
- ☐ Hold eyelids apart to **ensure** complete irrigation of the eye.
- ☐ Remove and discard contact lenses, if worn, after initial flushing.
- ☐ Do not use eye ointment.

For ingestion:

- ☐ DO NOT INDUCE VOMITING in casualties as this may lead to aspiration of the crude oil into the lung.
- ☐ If spontaneous vomiting occurs, lean the casualty forward to reduce risk of aspiration.
- ☐ Do not give anything by mouth.
- ☐ If casualty is drowsy or unconscious and vomiting, place on the left side with the head down.
- ☐ Monitor for breathing difficulties.

For inhalation exposure:

- ☐ Remove casualty to fresh air.
- ☐ If the casualty is not breathing, give artificial respiration.
- ☐ Give additional oxygen once breathing is restored.

[CDC, 2010b; DHHS, 2014; DHS, 2014]

3.2.3 Risks and crisis communication

During all phases of the incident, the public health authority should provide accurate, clear, consistent and easy-to-understand information to the population. The information should be repeated over more than one communication channel (e.g., radio, TV, social media, printed handouts) [WHO, 2009]. In disaster settings, it cannot be assumed that all the affected populations will have electricity [Genereux, 2015].

A spokesperson with public authority should be chosen and should be the sole person to give all the briefings. This spokesperson should be an excellent communicator, have good record of trustworthiness, and be able to inspire confidence in the population. The spokesperson should always tell the truth, even if it means stating "I don't know" [WHO, 2009].

General guidance on effective crisis communications is given in the CDC Crisis and Emergency Risk Communication (CERC) manual. CERC is described as an "attempt by public health professionals to provide information that allows individuals, stakeholders, and entire communities to make the best possible decisions for their well-being during a crisis or emergency." The CERC motto **"Be First, Be Right, Be Credible"** sums up an effective communications strategy [CDC, 2014b].

The CDC guide ***Simply Put*** provides guidance on transforming complicated scientific and technical information into communication materials that audiences of all health literary skills can relate to and understand [CDC, 2009].

A Good Practice Guide for efficient communication aimed at the political, technical and scientific authorities involved in Accidental Marine Pollution accidents based on experiences from the Prestige oil tanker spill is available from AMPERA [AMPERA, 2007].

3.3 What actions could support recovery?

The public health community has a significant role to play in recovery from a major crude oil incident working in collaboration with primary healthcare providers and other key stakeholders. The recovery phase from a crude oil incident includes health monitoring, clean-up, and restoration of the situation to as close to its pre-incident condition as practically possible [WHO, 2009].

Initially, in the response phase, the public health community may be tasked to organize both the physical and mental health care required to treat casualties in an efficient, compassionate and culturally sensitive manner. However, both physiological and psychological long-term medical care may be required to support community members during recovery and to monitor the health status of affected community members. For example, casualties suffering burns and traumatic injuries may require months or years of support. Mental health issues experienced by the population, due to job- or income-loss anxiety and ongoing litigation may also require long-term care.

In addition to treatment, the public health community can also assist and support the efforts of other groups to alleviate the social and economic needs (e.g., loss of income, job retraining) of affected individuals and communities.

Finally, in addition to oversight of the general population, individuals involved in the response (e.g., first responders and clean-up crews) may also require initial and long-term health monitoring given their potential for greater exposure.

The public health community also plays an important role in gathering and analyzing information. This is of particular concern given that the health effects of exposure to crude oil spills are poorly understood. Information gathering activities may range from performing rapid health assessments or determining immediate or longer-term needs for basic necessities or treatment, to conducting potentially multi-year epidemiological investigations aimed at understanding the population health effects of the incident.

Public health professionals may also be asked to comment on or oversee environmental monitoring efforts, as the incident may raise concern regarding the sufficiency of standard practices or the health significance of the results. An example of this may be ensuring that the monitoring of potentially contaminated drinking water supplies is sufficient and that the results of these analyses are communicated to concerned community members in an understandable and timely manner.

Supporting remediation and restoration efforts is another critical function over possibly an ongoing long time scale. For example, public health may be called upon to recommend or comment on clean up end points.

Finally, the public health community may be asked to synthesize epidemiological and environmental data and provide input into the formal assessment of impacts related to the incident.

As activities shift from the response to the recovery phase, it is critically important that public health authorities analyze the incident response itself, identify areas for improvement, and publish lessons learned from the incident. Although it is recognized that public health professionals often face heavy workloads because regular duties are deferred during the response, a detailed and publicly available narrative of the incident response is invaluable to guide future incidents within the same jurisdiction or in other jurisdictions. It also provides accountability and transparency when communicating with the public.

Finally, public health authorities have an opportunity to act on knowledge gained during an emergency by advocating for change, both internally by following up on "lessons learned," as well as by advocating and supporting regulations or legislation aimed at preventing or lessening the impacts of future incidents.

3.3.1 Population health follow-up research considerations

In the response and recovery timeframe of a major chemical incident, including a significant crude oil release, the public health community may wish to undertake or support environmental public health research, including characterizing environmental contamination levels in air, water and soils, human exposure across affected populations and their population health impacts. These studies can be a very valuable public health tool [WHO, 2009]. The benefits include:

- Providing data on the actual short- and long-term effects of a given chemical(s) on a diverse human population;
- Providing data on the effectiveness of the various medical countermeasures (e.g., drugs, decontaminants, support systems) employed (what was effective and what was not);
- Indicating actual or potential need for ongoing care (both physiological and psychological);
- Identifying additional needs of affected communities (e.g., job loss, retraining, housing);
- Assisting claimants seeking compensation for damage to their health; and
- Contributing to the scientific knowledge of the health outcome of chemical incidents (e.g., etiological studies of health outcomes, understanding of disease mechanisms).

The public health authority planning a follow-up study must clearly define the objectives of the study and should have the resources (work force, facilities, financial) for a multi-year study. If the authority does not have the required resources or ethical oversight, it might consider partnering with an academic institution.

another government department (federal, provincial, territorial, or municipal) or another group that has similar interests (national or international) [WHO, 1997].

Populations that should be considered for follow-up studies include:

- Obvious casualties of the incident;
- Persons who believe they were exposed but did not show any clinical signs;
- Responders;
- Clean-up crews;
- Potentially vulnerable or differentially impacted populations (e.g., children, elderly, smokers, Indigenous); and
- Control groups of similar backgrounds that could not have been exposed and did not claim to be exposed.

Broad participation of the affected populations and their retention in the study is essential. This can be encouraged by:

- Ensuring participants that their privacy will be guarded;
- Clearly explaining the need for the study and the benefits the study will bring to them and their community;
- Sponsoring community activities that promote the study;
- Offering participants modest compensation (e.g., monetary gifts, prizes) and covering any expenses incurred;
- Providing participants with access to their personal information (e.g., the results of any blood or tissue analyses conducted); and
- Informing participants on an ongoing basis of the study progress through newsletters, websites, etc.

Collecting good **baseline data** is essential. All participants should provide detailed health histories and information on lifestyle, occupation, and workplace factors that might confound exposures.

Information that should be obtained from those who were exposed, or believe they were exposed is listed in Checklist 9 [Levy, 2010; WHO, 2009].

Data should be collected from exposed and potentially exposed persons as soon as possible after the exposure. Any physiological testing should also be done as soon as possible [WHO, 2009].

Data for clean-up crews should include a complete physical examination with testing performed prior to potential exposure as well as after potential exposure (see reference NIOSH, 2010 for a "plan for pre-placement evaluation to gather medical information on workers prior to beginning oil spill response work").

Follow-up data should be obtained and testing done periodically on all participants to monitor changes in physiological and psychological status.

The **NIEHS GULF STUDY** on the health of clean-up workers and volunteers who responded to the 2010 Deepwater Horizon oil spill in the Gulf of Mexico is an example of an ongoing study. The research, led by the NIEHS with the support of many local community groups, is "designed to find answers to the questions that matter to oil spill clean-up workers and affected communities" [Sandler, 2014; NIH, 2017].

Follow-up studies on the psychological health of the residents of Lac-Mégantic are continuing (see Case Study – rail incident). [Généreux, 2015; Généreux, 2016; Vision, 2016; Santeestrie, 2017].

Checklist 6 provides links to epidemiological toolkits.

Checklist 9: Data collection considerations from participants in follow-up studies

☐ Participant's exact location at the time of, and during, the release;

☐ The duration of time participant was in the hazard zone;

☐ The type of activity participant was performing during exposure;

☐ Any protection participant may have had while in the hazard zone (e.g., clothing, PPE, shelter);

☐ Cleaning or decontamination undertaken by the participant;

☐ Any symptoms (e.g., burning, itching) the participant felt during the exposure and how long these symptoms lasted;

☐ How participant currently feels;

☐ Previous and current medical conditions;

☐ Allergies;

☐ Past and current use of alcohol, tobacco, and recreational drugs;

☐ Medications used at the time of exposure and since;

☐ Other exposures through hobbies (e.g., exposure to volatile organic compounds), recreational activities, and in their homes (e.g., running a diesel generator);

☐ Whether participant visited a doctor and/or received treatment; and

☐ Traumatic experiences such as loss of relatives, housing, or job.

[Levy, 2010; WHO, 2009]

Section 4. CASE STUDIES

Numerous accidents have occurred when transporting crude oil. Table 16 lists some of the accidents that resulted in significant changes in regulations in Canada and abroad.

Rail Accidents

Recent rail accidents involving the transportation of crude oil in Canada and the United States are described in Annex I: Derailments involving crude oil in Canada and the United States since the Lac-Mégantic derailment. The Lac-Mégantic derailment of 7 July, 2013 is the most significant accident involving crude oil in Canadian history (see Section 4.1).

Pipeline Accidents

Significant pipeline accidents in Canada and the United States involving crude oil are listed in Annex J1: Recent pipeline accidents involving crude oil in Canada and the United States and international accidents in Annex J2: Major international crude oil spills involving pipeline/storage tank/onshore wells. The 2010 Marshall, MI pipeline accident is described in Case Study 2.

Marine Spills

Marine oil spills involving ships are listed in Annex K: List of Major Crude Oil Spills – Marine Spills Involving Ships and those involving drilling platforms in Annex L: List of Major Crude Oil Spills Involving Drilling Platforms.

Two recent incidents in British Columbia (the Marathassa Incident of April 2015 and the grounding of the *Nathan E. Stewart*, Seaforth Channel, October 2016) which involved fuel oil and diesel, have raised concerns about shipping crude oil through environmentally sensitive or heavily populated areas. The incidents are discussed in Case Studies 3 and 4 respectively.

Table 16: Crude oil releases that resulted in significant changes in regulations

Incident	Date	Location	Description	Change
Lac-Mégantic derailment	Jul 6 2013	Lac-Mégantic, Quebec	A runaway train of 72 tank cars loaded with Bakken crude oil crashed. 63 cars derailed and exploded in the centre of town causing a massive fire. 47 people were killed, half the downtown area destroyed. About 5.6 million litres of crude oil was released.	See Section 4.1
Deepwater Horizon (DWH) (Macondo blowout)	Apr 20 2010	Gulf of Mexico	Fire and explosion occurred on the *Deepwater Horizon*, a semi-submersible drilling platform. The rig sank; a sea-floor oil gusher flowed for 87 days until capped on 15 Jul 2010 and sealed on 19 Sep 2010. 11 died, 17 were injured (3 critically). Total discharge was estimated as 4.9 million barrels. 2,500 to 68,000 square miles were affected. Total costs were $61.6 billion (Jul 2016) [Mufson, 2016]; litigation is ongoing. [National Commission, 2011].	New safety rules and regulations
Exxon Valdez	Mar 24 1989	Prince William Sound, Alaska	A super tanker grounded on Bligh Reef; eight of 11 tanks punctured; about 35,000 metric tonnes of Alaska North Slope crude escaped. Approx. 1,300 miles of shoreline were affected. At least 36,000 seabirds and 1,000 sea otters died. Exxon Mobil paid $3.5 billion in clean-up costs and $5 billion in legal and financial settlements. Court case for natural resource damages is still being pursued [ARLIS, 2017; Macalister, 2010].	The "double hull" amendment of 6 Mar 1992 promulgated and voted in for all vessels built after 6 Jul 1996 (MARPOL convention, rule 13F); USA Oil Pollution Act of 1990 [EPA, 1990]
Torrey Canyon	Mar 18 1967	near Lands End, Cornwall	A tanker ran aground on Pollard Rock on the Seven Stones Reef. Approx. 119,000 tonnes of Kuwait crude oil was lost into the sea or burned. More than 15,000 seabirds died. Many of the detrimental impacts of the spill later related to the high volume, high concentration, and high toxicity of the dispersant and detergents used. [ITOPF, 2014b]	Initiated first elements of the French, British, and European policies of prevention and response against large oil slick disasters.

4.1 CASE STUDY (rail incident): Lac-Mégantic derailment, 6 July 2013

At 22:50 Eastern Daylight Time (EDT) on July 5, 2013, a Montreal, Maine, and Atlantic Railway (MMA) train (MMA-002) arrived at Nantes, Quebec, carrying 7.7 million litres of petroleum crude oil (UN 1267) in 72 Class 111 tank cars and was parked on a descending grade on the main track. The engineer applied hand brakes on all five locomotives and two other cars, shut down all but the lead locomotive and left. The train was now held by the hand brakes and the air brakes on the lead locomotive. Shortly after the engineer left, the Nantes Fire Department responded to a 911 call reporting a fire on the train. The firefighters extinguished the fire and shut the lead locomotive down. Air pressure for the air brakes slowly reduced. Just before 1:00 a.m., the air pressure had dropped to a point at which the combination of locomotive air brakes and hand brakes could no longer hold the train and it began to roll downhill toward Lac-Mégantic, just over seven miles away [TSB, 2014a].

The train, having reached a top speed of 105 kph, derailed near the centre of the town at about 1:15 a.m. Fifty-nine of the 63 derailed tank cars were breached and released crude oil due to tank damage (see TSB, 2014b Table 3, Photos 16-23). Approximately 6 million litres of petroleum crude oil was quickly released. The fire, which burned for nearly two days, began almost immediately. The ensuing blaze and explosions left 47 people dead. Another 2,000 people were evacuated. Forty buildings and 53 vehicles were destroyed [TSB, 2014b]. One hundred fifteen businesses were destroyed, displaced, or rendered inaccessible [RC, 2013].

The hydrocarbon recovery and clean-up operation began as soon as the fire was extinguished and the site was stabilized, approximately two days after the derailment. About 740,000 litres of crude oil were recovered from the derailed tank cars. Crude oil migrated into the town's sanitary and storm sewer systems by way of manholes. An estimated 100,000 litres of crude oil ended up in Mégantic Lake and the Chaudière River by way of surface flow, underground infiltration, and sewer systems Approximately 31 hectares of land was contaminated [TSB, 2014b].

Public health response

Actions taken by the Public Health Department (PHD) of the Eastern Townships, in close collaboration with community-based organizations, during the impact phase emergency response (July-August 2013) included: providing direct services needed to protect the citizens and the on-site responders from health hazards (e.g., exposure to chemical, physical, and biological agents); risk assessments for on-site responders and clean-up personnel including firefighters, police, decontamination, team members, railway specialists, and contractors; initiation of epidemiological investigations; and risk communication to the general public and disaster workers [Généreux, 2015].

During the recovery operations phase (September 2013 to present), the PHD implemented a local surveillance system focusing on health issues related to the train derailment to keep track of the potential after-effects of the tragedy and conducted the first survey on population health (2014) [Généreux, 2015]. The second survey (2015) found that 67% of the residents of Lac-Mégantic continue to suffer moderate to severe post-traumatic stress and that one in six reported an increase in alcohol consumption [Généreux, 2016; Vision, 2016; Peritz, 2016]. The third survey (2016) indicated that (1) the population is still suffering from the consequences of the tragedy, particularly individuals who were more exposed and those experiencing difficulties in coping with the loss of a loved one; (2) psychological health is stable and even showing some improvement; and (3) use of medical and psychosocial services is increasing [Sante estrie, 2017].

Environmental monitoring and remediation

The Quebec Ministry of the Environment immediately deployed a mobile laboratory to measure air quality. Elevated concentrations of polycyclic aromatic hydrocarbons (PAH), nitrogen oxide, and total suspended particles (TSP) resulted in the Medical Health Officer ordering the evacuation of 1,000 people downwind of the disaster site [Genereux, 2015].

Municipal water systems that used the Chaudiere River were obliged to find alternate sources [Millette, 2014a].

The initial work focused on preventing the spread of contamination via preferential paths (e.g., sewers) into water courses [Millette, 2014b]. Surface water and sediment sampling stations were set up on Lac-Mégantic and the Chaudière River [Millette, 2014b; Galvez-Cloutier, 2015]. Contaminated soil, primarily in the impact zone and building foundations, was identified [Millette, 2014b].

Post-emergency remediation included the removal and treatment of 135,000 MT of contaminated soil, cleaning or replacement of storm sewers, treatment of 62 million litres of ground water to remove oil, and removal of sediment from the Chaudière River [Marcotte, 2015]. Contaminated soil was removed from the railway right of way and it was rebuilt in the original location [Millette, 2014b].

Three mobile monitoring stations to continuously monitor particulate matter (PM10) and Volatile Organic Compounds (VOCs) were set up at the perimeter of the site during remediation [Marcotte, 2015].

Safety recommendations

In 2014, the Transportation Safety Board (TSB) issued recommendations that it will monitor for compliance [TSB 2014a]

R14-01 (Jan 2014)	Enhanced protection standards **must** be put in place for Class 111 tank cars.
R14-02 (Jan 2014)	Railway companies should conduct strategic route planning and enhance train operations for all trains carrying dangerous goods.
R14-03 (Jan 2014)	Emergency response assistance plans (ERAPs) **must** be created when large volumes of liquid hydrocarbons, like oil, are shipped.
R14-04 (Aug 2014)	Canadian railways **must** put in place additional physical defences to prevent runaways.
R14-05 (Aug 2014)	Transport Canada **must** take a more hands-on role when it comes to railway safety management systems—making sure not just that they exist, but that they are working and that they are effective.

Legal issues

MMA has filed for bankruptcy protection [CBC, 2013a, CBC, 2013b].

The engineer, the manager of train operations and the railway's traffic controller were tried and found NOT guilty on 47 counts of criminal negligence causing death [Laframboise, 2018].

Six people employed by the rail company at the time of the incident and the two companies involved are facing two charges each under the *Railway Safety Act* for failing to ensure the train was properly braked before it was left unmanned for the night. A federal *Fisheries Act* charge for the crude oil that flowed into Lac-Mégantic and the Chaudière River after the accident has also been laid [CBC, 2015a].

A settlement of $446 million Cdn was approved for victims of the disaster [Sharp, 2015]. $113 million has been paid out for wrongful death claims [Canadian Press, 2016].

A class action suit against World Fuel Services and the Canadian Pacific Railway has been allowed to proceed [Canadian Press, 2015].

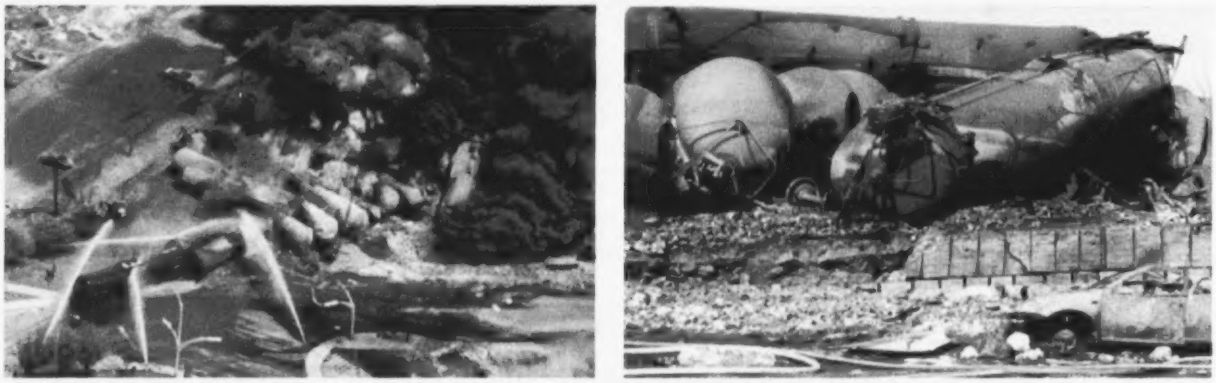
The Government of Quebec submitted a claim of $400 million against MMA to cover the estimated costs of the clean-up and reconstruction [Woods, 2014].

The Government of Quebec is suing CPR for damages of $409 million [CBC, 2015b].

Causes and contributing factors

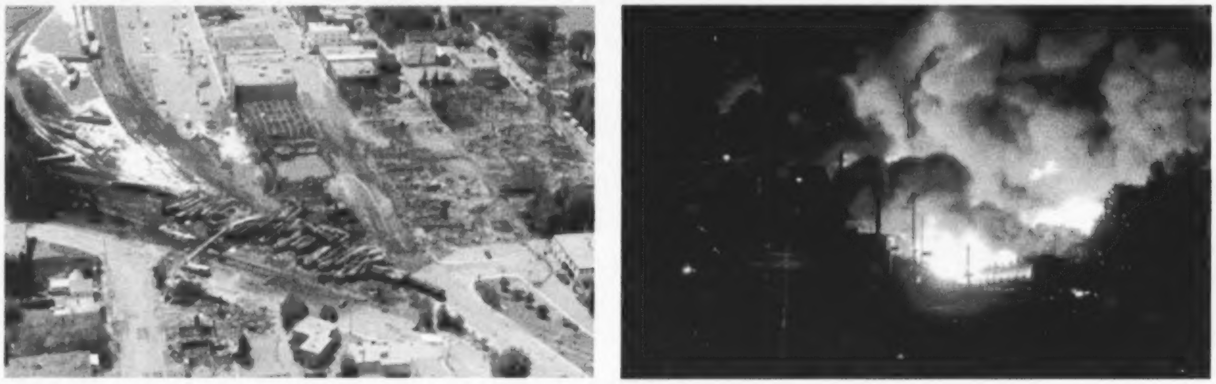
The Transportation Safety Board findings of the causes and contributing factors in the Lac-Mégantic derailment are detailed in Section 4.1 and Figure 11 [TSB, 2014b].

Note: TSB has an animation of the accident *Lac-Mégantic* MMA Train *Accident* - 6 July 2013 - *YouTube* [TSB, 2014c]. A technical assessment of lessons learned is given in reference Lacoursiere,2015.



Credit: Paul Chiasson/Canadian Press

Credit: Sûreté du Québec



Credit: Transportation Safety Board R13D0054

Credit: Vancouversun.com

Figure 10: Lac-Mégantic derailment

Transportation Safety Board (TSB) findings on the Lac-Mégantic derailment[11]

The TSB report listed 18 findings regarding the causes and contributing factors to the Lac-Mégantic derailment (see Figure 11) [TSB, 2014a; TSB, 2914b].

1. (The train) MMA-002 was parked unattended on the main line, on a descending grade, with the securement of the train reliant on a locomotive that was not in proper operating condition.
2. The seven hand brakes that were applied to secure the train were insufficient to hold the train without the additional braking force provided by the locomotive's independent brakes.
3. No proper hand brake effectiveness test was conducted to confirm that there was sufficient retarding force to prevent movement, and no additional physical safety defences were in place to prevent the uncontrolled movement of the train.
4. Despite significant indications of mechanical problems with the lead locomotive, the locomotive engineer and the Bangor, ME, rail traffic controller agreed

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[11] Available at http://www.tsb.gc.ca/eng/rapports-reports/rail/2013/r13d0054/r13d0054-r-es.pdf

that no immediate remedial action was necessary. The locomotive was left running to maintain air pressure on the train.

5. The failure of the non-standard repair to the lead locomotive's engine allowed oil to accumulate in the turbocharger and exhaust manifold, resulting in a fire.
6. When the locomotive was shut down as a response to the engine fire, no other locomotive was started, and consequently, no air pressure was provided to the independent brakes. Furthermore, locomotives with an auto-start system were shut down and not available to provide air pressure when the air brake system began to leak.
7. The reset safety control on the lead locomotive was not wired to initiate a penalty brake application when the rear electrical panel breakers were opened.
8. Because air leaked from the train at about one pound per square inch per minute, the rate was too slow to activate an automatic brake application.
9. When the retarding brake force provided by the independent brakes was reduced to about 97,400 pounds, bringing the overall retarding break force for the train to approximately 146,000 pounds, the train started to roll.
10. The high speed of the train as it negotiated the curve near the Mégantic West turnout caused the train to derail.
11. About one third of the derailed tank car shells had large breaches, which rapidly released vast quantities of highly volatile petroleum crude oil that ignited, creating large fireballs and a pool fire.
12. Montreal, Maine, and Atlantic Railway did not provide effective training or oversight to ensure that crews understood and complied with rules governing train securement.
13. When making significant operational changes on its network, Montreal, Maine, and Atlantic Railway did not thoroughly identify and manage the risks to ensure safe operations.
14. Montreal, Maine, and Atlantic Railway's safety management system was missing key processes, and others were not being effectively used. As a result, Montreal, Maine, and Atlantic Railway did not have a fully functioning safety management system to effectively manage risk.
15. Montreal, Maine, and Atlantic Railway's weak safety culture contributed to the continuation of unsafe conditions and unsafe practices, and compromised Montreal, Maine, and Atlantic Railway's ability to effectively manage safety.
16. Despite being aware of significant operational changes at Montreal, Maine, and Atlantic Railway, Transport Canada did not provide adequate regulatory oversight to ensure the associated risks were addressed.
17. Transport Canada, Quebec Region did not follow up to ensure that recurring safety deficiencies at Montreal, Maine, and Atlantic Railway were effectively analyzed and corrected. Consequently, unsafe practices persisted.
18. The limited number and scope of safety management system audits that were conducted by Transport Canada, Quebec Region and the absence of a follow-up procedure to ensure Montreal, Maine, and Atlantic Railway's corrective action plans had been implemented, contributed to the systemic weaknesses in Montreal, Maine, and Atlantic Railway's safety management system remaining unaddressed.

Changes in Canadian regulations governing the transportation of crude oil resulting from the Lac-Mégantic derailment

Since the Lac-Mégantic derailment on 7 July 2013, Transport Canada (TC) and the U.S. DOT have enacted numerous regulation changes that apply to the transportation of crude oil. These regulations required a minimum two crew for all trains transporting dangerous goods, detailed the securement of trains, required persons offering dangerous goods for transport or import by rail to have Emergency Response Assistance Plans (ERAPs), removed the least crash resistant DOT-111 tank cars from transporting dangerous goods, and resulted in the design of a new tank car (DOT-117) for hazardous good transport (see Annex M: Changes in regulations involving the transportation of crude oil in Canada and the United States resulting from the Lac-Mégantic derailment (not exhaustive) for regulation changes and description of DOT-117 tank car).

In 2015, Transport Canada issued requirements that (1) all companies transporting 1.5 million tonnes of crude oil per year in rail cars are required to have a minimum of $1 billion in liability insurance coverage and (2) a levy of $1.65 for every tonne of crude shipped is to be placed in a supplementary shipper-financed fund to be used in the event of a railway accident involving crude oil [TC, 2016].

The Canadian Pacific Railway (CPR) indicated that it would prefer not to transport crude oil and other dangerous goods [Atkins, 2015a] but was told that "Transport Canada does not have any plans to review the common carrier obligations" of the Canada Transportation Act that require railways to haul any and all legal goods in rail cars that meet safety standards [Atkins, 2015b].

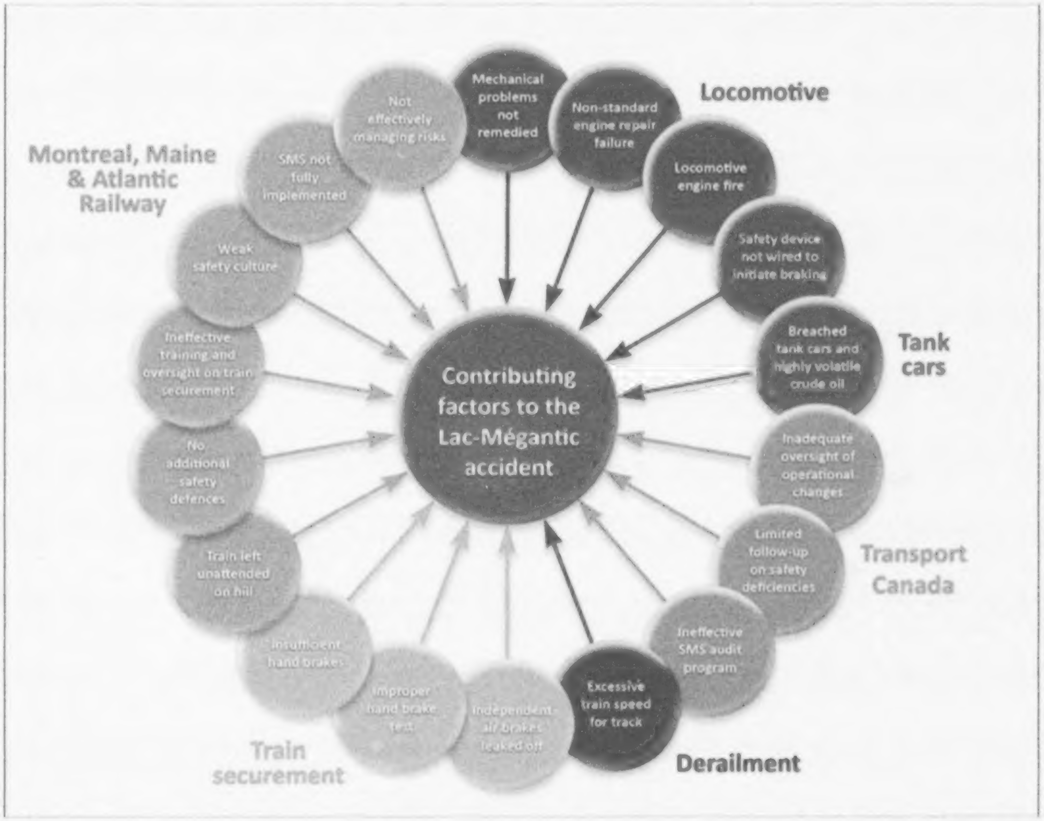
Contributing factors to the Lac-Mégantic accident
Locomotive
Mechanical problems not remedied
Non-standard engine repair failure
Locomotive engine fire
Safety device not wired to initiate braking
Tank cars
Breached tank cars and highly volatile crude oil
Transport Canada
Inadequate oversight of operational changes
Limited follow-up on safety deficiencies
Ineffective SMS audit program
Derailment
Excessive train speed for track
Train securement
Independent air brakes leaked off
Improper hand brake test
Insufficient hand brakes
Train left unattended on hill
No additional safety defences
Ineffective training and oversight on train securement
Montreal, Maine & Atlantic Railway
Weak safety culture
SMS not fully implemented
Not effectively managing risks

Figure 11: Causes and contributing factors to Lac-Mégantic derailment

4.2 CASE STUDY (pipeline incident): Marshall, MI, pipeline spill, 25 July, 2010

On Sunday, July 25, 2010, at 5:58 p.m., eastern daylight time, a segment of a 30-inch-diameter pipeline (Line 6B), owned and operated by Enbridge Incorporated (EI) ruptured in a wetland in Marshall, MI. The rupture occurred during the last stages of a planned shutdown and was not discovered or addressed for over 17 hours. During the time lapse, EI twice pumped additional oil (81% of the total release) into Line 6B during two start-ups; the total release was estimated to be 843,444 gallons of crude oil. The oil saturated the surrounding wetlands and flowed into the Talmadge Creek and the Kalamazoo River [NTSB, 2012b].

Environmental clean-up was completed in the fall of 2014 [EPA, 2015; EPA, 2016c]. Enbridge is required to continue to monitor the impacts of the spill on the environment [White, 2015]. The cost of the clean-up was $1.21 billion US [Ellison, 2016].

Health effects assessment

On July 26, the residents of six houses self-evacuated because of odours associated with the oil spill. Based on the concentration of benzene in the air, the health department issued a voluntary evacuation notice to about 50 homes on July 29 [NTSB 2012b].

The Michigan Department of Community Health (MDCH) set up a multi-faceted public health surveillance system that included health care provider reporting, community surveys, calls from the public to the Poison Control Center, and analysis of data submitted to the state's syndromic surveillance system. The surveillance system received 147 health care provider reports on 145 patients, identified 320 (58%) of 550 individuals with adverse health effects from four community surveys along the impacted waterways, identified symptomatic employees from one small worksite, and tracked 41 calls that were placed to the Poison Control Center by the public. Symptoms consistent with crude oil exposure (e.g., headache, nausea, and respiratory symptoms) were the predominant symptoms reported by exposed individuals in all reporting systems [Standbury, 2010]. No fatalities were reported [NTSB, 2012b].

Environmental monitoring

Public health surveillance was complemented by environmental monitoring. Air quality data collected during the response and clean-up indicated that people in the spill or work areas were not expected to have long-term health effects due to inhalation exposure [MDCH, 2014].

A detailed assessment of private drinking water wells in nearby communities was also undertaken [MDCH, 2013]. Two oil-related metals (nickel and iron) were detected at levels unlikely to harm human health. No oil-related organic chemicals were detected. However, two metals not present in the crude oil (arsenic and lead) were detected at levels potentially harmful to human health.

MDCH also assessed the health risk of contact with submerged oil located in sediment, concluding that although repeated contact with sediment was unlikely to induce long-lasting health effects or cancer, temporary skin irritation was possible and contact should be avoided [MDCH, 2012].

Safety recommendations and legal implications

Shortly after the incident, the National Transportation Safety Board (NTSB) issued an accident report containing 19 specific recommendations regarding pipeline inspections, training, emergency response plans, oversight, and accountability [NTSB, 2012b]. Furthermore, the Department of Transportaiion's Pipeline and Hazardous Materials Safety Administration (PHMSA) proposed a $3.7 million US civil penalty in recognition of multiple regulatory violations [PHMSA, 2012].

A class action suit awarding spill-related expenses to homeowners and tenants within 1,000-feet (0.3 km) of the shoreline was settled in December 2014 [Parker, 2014].

4.3 CASE STUDY (marine oil spill): Grounding of the Nathan E. Stewart, Seaforth Channel, October 2016

On Oct 13 01:00 PST the *Nathan E. Stewart*, a tug owned by Kirby Offshore Marine, was towing an empty barge, when it grounded on Edge Reef near Athlone Island in Seaforth Channel, BC. A Canadian Coast Guard search and rescue vessel from Bella Bella rescued the crew. The tug, which itself was carrying 237,000 litres of marine diesel fuel and other hydrocarbons, sank in nine metres of water at 09:00 PST. Three fuel tanks were compromised and were leaking.

Response:

By 10:00 PST, clean-up crews from the Canadian Coast Guard and members of the local Heiltsuk community arrived, but were hampered in response efforts due to limited equipment availability. Bad weather further hindered efforts to place a containment boom around sensitive shoreline. By 17:00 PST, provincial crews were on-site and additional clean-up resources began arriving from Prince Rupert and Vancouver, including several large Coast Guard vessels.

On Oct. 17, extraction of the fuel from the tug's tanks commenced using a hot tapping method. Extraction was completed on Oct 24 and recovered 110,000 litres of diesel. Approximately the same amount was missing and presumed to have leaked into the ocean. Shoreline damage was evident.

On Oct 24, Transport Canada launched marine investigation M16P0378 into the grounding of the tug *Nathan E. Stewart* and tanker barge DBL 55 [TSB, 2016].

On Nov 11, the tug was towed into deeper waters and lifted onto a salvage barge on Nov 14. [CBC, 2016].

The extent of shoreline damage and effects on marine resources (e.g., clam beds) are under evaluation. Fisheries and Oceans Canada (DFO) closed the area around the spill to shellfish harvesting [Lindsay, 2017].

Heath effects on the local Heiltsuk community [NCCEH, 2016]

Impacts to community health and well-being are currently under evaluation. However, a rapid health assessment as well as community feedback regarding impacts revealed:

- mental and physical impacts including oil exposure, shock, and exhaustion;
- food safety fears in a community dependent on marine resources;
- loss of income and cultural connectivity dependent on harvesting marine resources;
- anger, alienation, and discrimination; and
- lack of recognition of immediate and long-term health needs.

The Heiltsuk community lost $200,000 in income from the clam beds [Lindsay, 2017].

4.4 CASE STUDY (marine oil spill): Marathassa Incident, April 2015

A sheen of oil was observed in English Bay on 8 April 2015 at16:48 PST. The Captain and representatives of M/V *Marathassa* initially denied that early on the morning of April 8, 2015 the ship had discharged an unknown quantity of intermediate fuel oil (suspected to be IFO 3802) into English Bay on April 8.

Response:

The Canadian Coast Guard activated the Unified Command as per the Incident Response System. Oil containment and recovery by West Coast Marine Response Corporation (WCMRC) started at 21:25 on April 8 with on-water recovery operations. A boom was placed around M/V Marathassa at 03:25 on April 9. A National Aerial Surveillance Program (NASP) flight at 12:20 hours on April 9 estimated that approximately 2,800 litres of fuel oil remained on the water. On-water recovery operations were completed on April 12, recovering an estimated 1,400 litres of oil. Additional work on search, recovery, vessel cleaning, and decontamination continued until April 23. Shoreline assessment and clean up using the Shoreline Cleanup and Assessment Technique (SCAT) took place from April 9 to 24. Additional survey and monitoring programs included (1) aerial overflights and underwater surveys to determine surface and subtidal oil extent; (2) oil, sediment, water, and biological sampling and analysis; and (3) wildlife rescue and rehabilitation.

Operational updates were provided by Fisheries and Oceans Canada (DFO) throughout the response [DFO, 2015].

DFO closed Burrard Inlet to all recreational fishing for shellfish and groundfish [Johnson, 2015].

Beaches in Vancouver and North Vancouver were closed for over a month [CBC News, 2015c]

Recommendations:

Key recommendations from the Butler report [Butler, 2015] for improved spill response include:

- ensuring the Coast Guard has adequate staff to respond to a major marine pollution incident in the region at any given time;
- continuing implementation of the Incident Command System, including exercises with all partners, First Nations, provincial and municipal partners, and non-governmental organizations as part of the plan;
- ensuring accurate information is released by Unified Command and/or Incident Command as soon as possible regarding the type, quantity, and fate and effects of a pollutant, including any information that is related to public health concerns; and
- developing a rapidly deployable communications and IT system that facilitates a more effective and timely electronic interface with partner agencies during an incident.

Legal issues:

Charges under the *Canada Shipping Act*, the federal *Fisheries Act*, and the *Canadian Migratory Birds Act* were filed against the M/V *Marathassa* and Alassia Newships Management Inc., the Greece-based ship's owners in 2017 [Hunter, 2017].

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Annexes

Annex A: Composition and basic analysis of crude oils

Annex B: Crude oil pipelines in Canada and the United States

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Annex M: Changes in regulations involving the transportation of crude oil in Canada and the United States resulting from the Lac-Mégantic derailment (not exhaustive)

Annex A: Composition and basic analysis of crude oils

Crude Source	Paraffins % vol	Naphthenes % vol	Aromatics % vol	Sulfur % wt	API Gravity (° API)	Nickel (mg/kg)	Vanadium (mg/kg)
Access Western Blend				3.91	21.8	71.8	190.2
Bakken				0.1	40-43		
BC Light				0.64	40.4	3.4	9.9
Brent Blend	50	34	16	0.37	38.3		
Christina Dilbit Blend				3.87	21.6	70.8	183.8
Cold Lake Blend				3.77	21.1	64.7	167.0
Dubai				2.00	31		
Hibernia Blend				0.44	35.1		
Prudhoe Bay heavy	27	36	28	0.9	28		
Russian Export Blend				1.2	32		
Saudi Heavy	60	20	15	2.1	28		
Saudi Light	63	18	19	2.0	34		
South Louisiana Light	36.6	44.8	18.6	0.25	35		
Venezuela Heavy	35	53	12	2.3	24		
Venezuela Light	52	34	14	1.5	30		
Wabasca Heavy				4.11	20	53.8	145.6
West Texas Intermediate				0.42	37-42		
West Texas sour	46	32	22	1.9	32		
Western Canadian Blend				3.11	20.5	46.9	99.6
Western Canadian Select				3.51	20.9	59.0	141.0

Note: Basic analysis may provide data on: Micro Carbon Residue (MCR), a crude oil assay property describing the carbon residue formation tendency of a crude oil, Total Acid Number (TAN), a measurement of acidity that is determined by the amount of potassium hydroxide in milligrams that is needed to neutralize the acids in one gram of oil, BTEX (benzene, toluene, ethyl benzenes, xylenes) and "light ends", alkanes from C1 to C10. The Crudemonitor provides detailed information on western Canadian crudes [Crudemonitor, 2017].

Producers' Safety Data Sheets (SDS) should be consulted for information on a specific crude oil.

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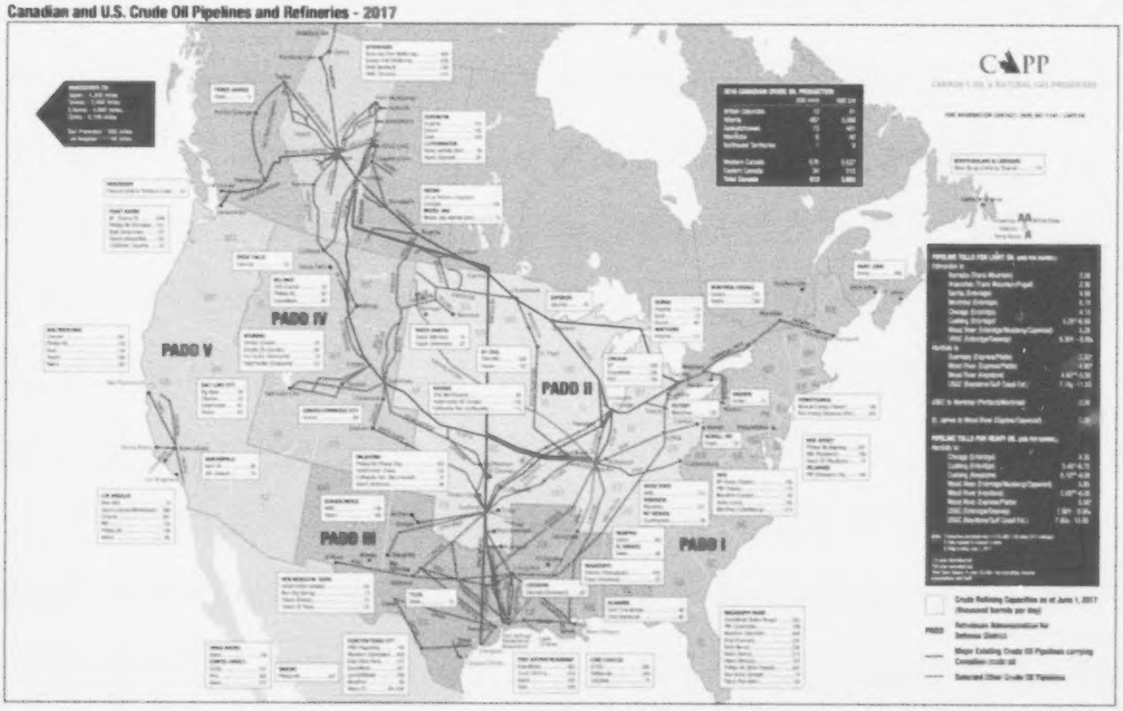
Annex B: Crude oil pipelines in Canada and the United States

Canadian and U.S. Crude Oil Pipelines and Refineries - 2017



Source: Canadian Association of Petroleum Producers (CAPP)

Note: The Canadian Energy Pipeline Association (CEPA) has an interactive map showing where transmission pipelines and facilities are located across Canada [https://cepa.com/en/].

Annex C: Classification of tankers according to size

AFRA scale		Flexible market scale		Standard Dimensions (m) (L = length, W = width, D = draught)
Class	Size in DWT	Class	Size in DWT	
General Purpose tanker	10,000–24,999	Product tanker	10,000 – 60,000	
Medium Range tanker	25,000–44,999	Panamax	60,000 – 80,000	L = 289.6, W = 32, D = 12
LR1 (Large Range 1)	45,000–79,999	Aframax	80,000 – 120,000	L = 245, W = 34, D = 20
LR2 (Large Range 2)	80,000–159,999	Suezmax	120,000 – 200,000	L = 285, W = 48, D = 20.1
VLCC (Very Large Crude Carrier)	160,000–319,999	VLCC	200,000 – 320,000	L = 330, W = 58, D = 31
ULCC (Ultra Large Crude Carrier)	320,000–549,999	ULCC	320,000 – 550,000	L = 415, W = 63, D = 35

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Annex D: Examples of reported toxicological health effects from acute crude oil exposure

General manifestations	• general sense of tiredness (Campbell, 1993) • fatigue (Janjua, 2006; Lee, 2010; D'Andrea, 2014) • back pain (Morita, 1999; Schvoerer, 2000; Sim, 2010; Na, 2012)
Respiratory*	• throat irritation (sore throat) (Campbell, 1993; Lyons, 1999; Morita, 1999; Suarez, 2005; Meo, 2009; Lee, 2010; Perez, 2016) • runny nose (Meo, 2009; Sim, 2010; Perez, 2016) • cough (Meo, 2009; Lee, 2010, D'Andrea, 2014) • shortness of breath (Lee, 2010; D'Andrea, 2014) • adverse affect on lung function parameters [Meo, 2009]
Gastrointestinal	• nausea (Campbell, 1993; Schvoerer, 2000; Carrasco, 2007; Janjua, 2006; Lee, 2010) • vomiting (Carrasco, 2006)
Central Nervous System	• headache (Campbell, 1993; Lyons, 1999; Morita, 1999; Bosch, 2003; Janjua, 2006; Sim, 2010; D'Andrea, 2014) • dizziness (Carrasco, 2006; Lee, 2010: D'Andrea, 2013) • tingling of limbs (Lee, 2010) • hot flushing (Lee, 2010) • drowsiness (Sim, 2010)
Dermatological (skin)	• skin lesions including erosion, blister, rash in clean-up workers who had direct contact with crude oil [D'Andrea, 2013; Sim, 2010] • itchy skin (Ordinioha, 2010; Lee, 2010) • skin rash (Bosch, 2003)
Ophthalmological (eye)	• itchy eyes (Campbell, 1993; Carrasco, 2006) • sore eyes (Lyons, 1999; Ordinioha, 2010; Lee, 2010)
* Respiratory effects may occur from: (a) direct toxicity from inhaling crude oil fumes or from inhaling fire smoke (thermal or chemical burns) (b) respiratory aspiration of gastrointestinal fluids particularly in unconscious subjects; (c) via gastrointestinal absorption of hydrocarbons with subsequent systemic pulmonary toxicity	
Note: See Annex E: Epidemiological studies on physical/physiological effects experienced by humans exposed to oil spills for summaries of reports of toxicological health effects	

Note: To show generality of toxicological health effect one example was chosen from each incident (see Annex D: Examples of reported toxicological health effects from acute crude oil exposure for summaries of reports).

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Annex E: Epidemiological studies on physical/physiological effects experienced by humans exposed to oil spills

Note: Studies on genotoxicity, immunotoxicity and endocrine toxicity are excluded in Table. Laffon et al (2016) discusses these.

Key to reviewers:

H = Ha M, Lee WJ, Lee S, Cheong HK (2008) A literature review on health effects of exposure to oil spill. J Prev Med Public Health. 2008 Sep;41(5):345-54. PMID: 18827503

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D&R = D'Andrea MA, Reddy GK (2014) Crude oil spill exposure and human health risks. J Occup Environ Med. 2014 Oct;56(10):1029-41 PMID: 25285825

L = Laffon B, Pásaro E, Valdiglesias V (2016) Effects of exposure to oil spills on human health: Updated review. J Toxicol Environ Health B Crit Rev. 2016;19(3-4):105-28. PMID: 27221976

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Reviewer	Reference	Study Design	Methods	Results
Braer (5 January 1993) Southwest Shetland islands; UK; 85,000 tons of crude oil released over a 6-day period; management included aerial spraying of dispersants.				
H, A, L&N, D&R, E	Campbell D, Cox D, Crum J, Foster K, Christie P, Brewster D (1993) Initial effects of the grounding of the tanker Braer on health in Shetland. The Shetland Health Study Group. BMJ. 1993 Nov 13;307(6914):1251–5. PMID: 8281057	Cross-sectional study. Environmental sampling started on 10 Jan; health sampling from 13-21 Jan.	420 exposed residents within 4.5 km of the site of tanker's grounding, 92 controls. Questionnaires on demographic details; smoking and alcohol consumption; perception of health and reported presence or absence of specific symptoms; peak expiratory flow; results of haematology, liver and renal function tests, and blood and urine toxicology.	Among exposed vs. control residents, higher incidences of headache (odds ratio, 5.75; 95% CI, 2.47–14.08), throat irritation (odds ratio, 7.03; 95% CI, 3.02–17.18), and itchy eyes (odds ratio, 6.72; 95% CI, 2.53–19.45), particularly during days 1 and 2 after exposure or when odour was present. Skin irritation, nausea, tiredness also noted. No significant difference in lung, liver, or renal function or urine or blood analysis compared to controls. Toxicological studies did not show any exposure known to affect human health. Urinary toluene metabolite detected in a larger percentage of the exposed.
H, A, G, D&R, E	Crum JE. (1993) Peak expiratory flow rate in schoolchildren living close to Braer oil spill. BMJ. 1993 Jul 3;307(6895):23–4. 64 PMID: 8343663	Cross-sectional study of children living within 5 km of the wreck site.	44 children three days after oil spill, 56 children 9-12 days after oil spill. peak expiratory flow rate (PEF) levels on day 3 and forced expiratory volume (FEV) and forced vital capacity (FVC) on days 9–12. Use of Mini-Wright flow meter and pocket Spirometer.	PEF and lung function tests within normal limits in healthy and in six asthmatic children at 3, 9, or 12 days after the spill.

Reviewer	Reference	Study Design	Methods	Results
H, A, G, D&R, E	Campbell D, Cox D, Crum J, Foster K, Riley A (1994) Later effects of grounding of tanker Braer on health in Shetland. Br Med J. 1994 Sep 24;309(6957):773–4. PMID: 7950562	follow up of Campbell et al Jan 1993 study in Jun 1993.	344 of the 420 exposed residents and 77 of the 92 controls in earlier study to evaluate later effects. General health questionnaire. Peak expiratory flow, urine analysis, hematology, and liver and renal function tests.	More exposed residents than controls reported poor health ($P<0.05$) or deteriorating health ($P<0.001$) and breathless-ness on exertion (odds ratio, 4.81; 95% CI, 1.09–29.92). Exposed residents had a lower rate of throat and eye irritation and headaches than immediately after the spill. No significant difference in lung, liver, or renal function or urine or blood analysis compared to controls.
Sea Empress (15 February 1996) Milford Haven; 73,000 tons of crude oil released near a highly populated area, with strong odours detectable in the area; 200 km of coast line affected.				
H, A, L&N, G, D&R, E	Lyons R, Temple J, Evans D (1999) Acute health effects of the Sea Empress oil spill. J Epidemiol Community Health. 1999;53:306–10. PMID: 10396538	Retrospective cohort study; seven weeks after spill asking about symptoms during the first four weeks after the spill.	Postal questionnaire including demographic details, a symptom checklist, beliefs about health effects of oil and the Hospital Anxiety and Depression and SF-36 mental health scales. 539 exposed residents, 550 controls in towns on the coast of Wales.	Significantly increased rates of headache, sore eyes, and sore throat among exposed residents attributed to toxicologic effects of exposure and increased anxiety and depression scores attributed to mental health effects of the spill. Total of 23% of exposed residents believed oil spill to have affected their health, vs. 2% of controls. Residence in exposed community associated with higher anxiety scores ($P = 0.04$) and depression scores ($P = 0.049$) and lower SF-36 mental health scores ($P = 0.002$).

Reviewer	Reference	Study Design	Methods	Results
H, A, D&R, E	Gallacher J, Bronstering K, Palmer S, Fone D, Lyons R (2007) Symptomatology attributable to psychological exposure to a chemical incident: a natural experiment. J Epidemiol Community Health. 2007 Jun;61(6):506–12. PMID: 17496259	Cross-sectional study seven weeks after spill, focused on acute psychological symptoms attributable to exposure vs. perception of exposure.	Postal questionnaires of acute toxic and non-toxic symptoms sent to a random sample of 1585 adults aged 18–65 year in four exposed coastal towns and two control coastal towns. 1089 men and women aged 18-65 years responded for a response rate of 69% (539 exposed residents and 550 controls). Scored on Hospital Anxiety and Depression Scale.	Physical health impacts were related to physical exposure, mental health impacts (including anxiety) were associated with perceived risk, and were observed in both impacted and non-impacted towns.
Nakhodka (2 January 1997) Northeast Oki Island, Sea of Japan, Japan; greater than 6,000 tons of bunker C released.				
H, A, L&N, G, D&R, E	Morita A, Kusaka Y, Deguchi Y, Moriuchi A, Nakanaga Y, Iki M, Miyazaki S, Kawahara J (1999) Acute health problems among the people engaged in the cleanup of the Nakhodka oil spill. Environ Res. 1999;81(3):185–94. PMID: 10585014	Cross-sectional study of acute health problems three weeks after spill.	282 local residents engaged in clean up of heavily exposed island between 7 Jan and 20 Jan; average of 4.7 days for men and 4.3 for women worked on clean-up activities. Home interview by public health nurses. Total of 97 urine samples obtained. Four workers use personal air samplers to assess benzene, toluene and xylene during clean up.	Lower back pain, headaches, eye and throat irritation and leg pain related to duration of clean-up activities. These as well as fatigue and nausea did not improve immediately. At least one symptom found in 78.7% of women and 56.7% of men. Highest benzene level was 1.85 ppb (for comparison, allowable 8-hr average in U.S. workplace is 1000 ppb). No increase was found in urinary indicator of benzene exposure among workers. Three workers had slightly increased levels of urinary indicator of toluene exposure.

Reviewer	Reference	Study Design	Methods	Results
Erika (12 December 1999) South Penmarch, Brittany, France; total of 28,000 tons of heavy fuel oil spilled; approximately 500 km of shoreline affected.				
A, G, D&R	Schvoerer C, Gourier-Frery C, Ledrans M, et al. (2000) Epidemiologic study on short-term health alterations in people participating in the cleanup of places contaminated by Erika oil (in French) [http://www.invs.sante.fr/publications/erika3/rapmaree_dist.pdf]	Cross-sectional study of acute health symptoms.	1465 professionals and volunteers involved in cleanup. Postal questionnaires and telephone interviews.	7.5% of the individuals experienced some type of wound and 53% some health problem (30% lumbar pain, 22% migraine, 16% dermatitis, 9% ocular irritation, 7% respiratory problems and 6% nausea). The duration of the cleaning work identified as a risk factor. Women were at higher risk for acute health effects. Among volunteers, lack of safety information was associated with increased risks of skin irritation (odds ratio, 1.83; 95% CI, 1.21–2.77), musculoskeletal problems (odds ratio, 2.36; 95% CI, 1.30–4.30), and back pain (odds ratio, 1.45; 95% CI, 1.07–1.96).
H, A, G, D&R	Baars BJ (2002) The wreckage of the oil tanker 'Erika' human health risk assessment of beach cleaning, sunbathing and swimming. *Toxicol. Lett.* 128: 55–68. PMID: 11869817	Potential toxicological risk assessment for people involved in cleaning activities and for tourists.	Risk characterizations on the basis of suppositions of the potential exposure during cleaning and tourist activities. PAH and benzene exposure levels based on extrapolation from measured values.	Risk for the general population limited. Increased risk for developing skin irritation and dermatitis, and very limited risk for developing skin tumors for people who had bare-handed contact with the oil. Long-term cancer risks were reported to be generally negligible.

Reviewer	Reference	Study Design	Methods	Results
H, A, G, D&R	Dor F, Bonnard R, Gourier-Fréry C, Cicolella A, Dujardin R, Zmirou D (2003) Health risk assessment after decontamination of the beaches polluted by the wrecked ERIKA tanker. Risk Anal 2003;23:1199-208. PMID: 14641894	Cancer-risk analysis based on measurement of PAHs on beaches and in water four months after spill and modeling of atmospheric levels of volatile PAHs.	Determination of the 16 PAH selected by EPA in sand, water and surface of rocks from 36 cleaned-polluted beaches and seven control beaches. Seven possible scenarios of exposure for people using the beaches in tourist activities (children, adults and pregnant women) or working activities.	Sand and water slightly polluted, with values similar to those found in control beaches; rocky areas still highly polluted. No lethal risk found for a young child who had accidentally ingested a small ball of fuel. Life-long excess risks for skin cancer and for all other cancers about 10^{-5} in scenarios including contact with the polluted rocks. Hazard quotient for teratogenic effects very small, except in scenarios where pregnant women walked among rocks containing high pollution levels.
Oil company pipeline, Nigeria (2000)				
L&N, D&R	Ordinioha B, Sawyer W (2010) Acute health effects of a crude oil spill in a rural community in Bayelsa State, Nigeria. Niger J Med. 2010 Apr-Jun;19 (2):140-14. PMID: 20642076	Retrospective cohort study, with a comparison control group using.	Interviewer–administered questionnaire and focus group discussions. 210 exposed residents, 210 controls.	Significant differences in diarrhea, sore eyes, itchy skin, occupational injuries between exposed residents and controls.

Reviewer	Reference	Study Design	Methods	Results
Prestige (19 November 2002) Galicia, Spain; 63,000 tons of oil were released, rapidly at first and more slowly over a period of months; more than 100,000 people were involved in the response; 900 km of coast line, from northern Portugal to southern France affected.				
L&N, D&R	Bosch X (2003) Exposure to oil spill has detrimental effect on clean-up workers' health. Lancet. 2003;361:147. PMID: 12531588	Report on clean-up workers who sought medical attention for complaints between 29 Nov and 3 Jan.	711 clean-up workers.	Conjunctivitis (167), headache (138), sore throat (137), breathing difficulty (115), vomiting (103), skin rash (73), abdominal pain (42).
H, A, G, L&N, D&R, E	Suárez B, Lope V, Pérez-Gómez B, Aragonés N, Rodríguez-Artalejo F, Marqués F, et al (2005) Acute health problems among subjects involved in the clean-up operation following the Prestige oil spill in Asturias and Cantabria (Spain). Environ Res. 2005 Nov;99(3):413–24 PMID: 16307984	Cross-sectional. Acute health problems among subjects involved in the clean-up operation after the spill. Data collected in Jun 2003.	Structured telephone interview of stratified sample of 799 workers (265 paid workers, 266 volunteers,133 seamen 135 bird cleaners) - response rate of 62.5%. Structured questionnaire asked information on specific tasks, number of working days, use of protective materials, and acute health effects. Univariate and multivariate analyses.	Injury rate highest among bird cleaners (19%); rates of headache (28.4%) and throat and respiratory tract disorders (30.4%) highest among seamen. On multivariate analysis, greater than 20 days' work in highly polluted areas, vs. fewer days' work, associated with headache (OR, 2.62; 95% CI, 1.23–5.60); nausea, vomiting, and dizziness (OR, 2.50; 95% CI, 1.09–5.74); and throat and respiratory problems (OR, 3.74; 95% CI, 1.89–7.40). A larger number of symptoms (vs. a smaller number) associated with a reported perception of unpleasant odours and with eating while working with oil.

Reviewer	Reference	Study Design	Methods	Results
H, A, G, L&N, D&R, E	Carrasco JM, Lope V, Pérez-Gómez B, et al (2006) Association between health information, use of protective devices and occurrence of acute health problems in the Prestige oil spill clean up in Asturias and Cantabria (Spain): a cross-sectional study. BMC Public Health. 2006 Jan;6:1. PMID: 16390547	Cross-sectional study examining effects of providing safety and health information to response workers.	Telephone survey 799 clean-up workers (133 seamen, 135 bird cleaners, 266 volunteers and 265 paid workers) six months after the spill. Same interview and population as used by Suarez et al. (2005) Odds ratios based on logistic regression.	Health-protection briefing associated with use of protective devices and clothing. Uninformed subjects registered a significant excess risk of itchy eyes (OR: 2.89; 95%CI:1.21-6.90), nausea/ vomiting/ dizziness (OR:2.25; 95%CI:1.17-4.32) and throat and respiratory problems (OR:2.30; 95%CI:1.15-4.61). Significant excess risk of headaches (OR:3.86: 95%CI:1.74-8.54) and respiratory problems (OR:2.43; 95%CI:1.02-5.79) among uninformed paid workers. Seamen, the most exposed group, were the worst informed and registered the highest frequency of toxicological problems.
H, A, G, D&R, E	Zock J-P, Rodríguez-Trigo G, Pozo-Rodríguez F, et al. (2007) Prolonged respiratory symptoms in clean-up workers of the Prestige oil spill. Am J Respir Crit Care Med. 2007 Sep 15;176(6):610–6. PMID: 17556713	Longitudinal cohort study 12-24 months after the spill on association between participation in clean-up work and respiratory symptoms in exposed.	Questionnaire given to members of fishing cooperatives (4594 men and 2186 women) - response rate of 76%. Comparison of members involved and members not involved in spill response.	Prevalence of lower-respiratory-tract symptoms (LRTS) significantly higher among exposed members than among unexposed members (odds ratio, 1.73; 95% CI, 1.54–1.94) LRST increased with the number of exposed days, exposed hours per day, number of activities and lack of PPE. Although LRTS risk decreased over time, it remained elevated at 20 months.

Reviewer	Reference	Study Design	Methods	Results
D&R, E, L	Rodríguez-Trigo G, Zock J-P, Pozo-Rodríguez F, et al. (2010) Health changes in fishermen 2 years after clean up of the Prestige oil spill. Ann Intern Med 2010 Oct 19,153 (8):489–98. PMID: 20733177	Cohort study (preceded by Zock et al., 2007) of 501 exposed and 177 non-exposed fishermen, two years after the spill.	Questionnaire on participation in clean-up activities. Respiratory symptoms, forced spirometry, methacholine bronchial provocation test (MBPT), markers of oxidative stress, airway inflammation, and growth factor activity in exhaled breath condensate.	Exposed fishermen demonstrated increased risk for lower-respiratory-tract symptoms (risk difference, 8.0 [95% CI, 1.1 to 14.8]). No difference in lung function was observed with respect to controls. The risk for elevated levels of exhaled 8-isoprostane, vascular endothelial growth factor, and basic fibroblast growth factor seemed to increase with intensity of exposure to clean-up work.
D&R, E, L	ZockJ-P, Rodríguez-Trigo G, Rodríguez-Rodríguez E, et al. (2012) Persistent respiratory symptoms in clean-up workers 5 years after the Prestige oil spill. Occup Environ Med 2012 Jul,69(7):508–13. PMID: 22539655	Cohort study (preceded by Zock et al. ,2007) of 466 exposed and 156 non-exposed fishermen, 5 years after the spill.	Questionnaire on participation in clean-up activities, on upper- and lower-respiratory-tract symptoms, allergic conditions, anxiety and beliefs about the effects of the oil spill on the participant's own health.	The prevalence of lower-respiratory-tract symptoms (including wheeze, shortness of breath, cough and phlegm) slightly decreased in both groups, but remained higher among the exposed (RR 1.4, 95% CI 1.1 to 1.9). Risk of having persistent respiratory symptoms (reported both at baseline and at follow up) increased with the degree of exposure: RR ratio 1.7 (95% CI 0.9 to 3.1) and 3.3 (95% CI 1.8 to 6.2) for moderately and highly exposed, respectively, when compared with those without any symptoms. Findings for nasal symptoms and for respiratory medication usage were similar.

Reviewer	Reference	Study Design	Methods	Results
E, L	Zock, J-P, Rodríguez-Trigo G, Rodríguez-Rodríguez E, et al. (2014) Evaluation of the persistence of functional and biological respiratory health effects in clean-up workers 6 years after the Prestige oil spill. Environ Int 2014 Jan;62:72–77. PMID: 24184661	Cross-sectional (preceded by Zock et al., 2007, 2012) and compared with previous evaluation (Rodríguez-Trigo et al. 2010). Four-year follow up, six years after cleanup to determine persistence of functional and biological respiratory health effects in never-smoking fishers exposed (n = 158) and non-exposed (n = 57) to the oil.	Questionnaire on participation in clean-up activities. Respiratory symptoms, forced spirometry, methacholine bronchial provocation test (MBPT), markers of oxidative stress, airway inflammation, and growth factor activity in exhaled breath condensate.	During the 4-year follow-up period lung function, bronchial hyperresponsiveness and the levels of respiratory biomarkers of oxidative stress and growth factors had deteriorated notably more among non-exposed than among exposed. At follow up, respiratory health indices were similar or better in clean-up workers than in non-exposed. No clear differences between highly exposed and moderately exposed clean-up workers were found. Long-term respiratory health effects in clean-up workers six years after the Prestige oil spill was not found.
Tasman Spirit (23 July 2003) off Karachi, Pakistan, in July 2003; tanker contained 68,000 tons of crude oil, an estimated 28,000 tons of which came ashore; 11,000 tons evaporated, producing a pungent odour. Volatile organic compounds in nearby areas were at concentrations of 44 to 179 ppm for at least 15 to 20 days.				
H, A, G, L&N, D&R, E	Janjua NZ, Kasi PM, Nawaz H, Farooqui SZ, et al. (2006) Acute health effects of the Tasman Spirit oil spill on residents of Karachi, Pakistan. BMC Public Health. 2006 Jan;6:84. PMID: 16584541	Cross-sectional survey. Acute health effects in 216 exposed community members. Control group A of 83 residents living 2 km from the exposed community; control group B of 101 residents living 20 km from the exposed community.	Household interviews. Questionnaires on acute health symptoms and on perception about the role of oil spill in producing ill health, and anxiousness about the effect of oil spill on health. Symptom score based on response to each of 48 symptoms.	Mean symptom scores were 14.1 in the exposed group, 4.4 in control group A, and 3.8 in control group B. Exposed group had significantly increased rates of ocular, respiratory, and skin symptoms, as well as headache, irritability, fever, and general fatigue. Rates of wheezing and shortness of breath during the period of the spill greater in the exposed group (6%) than in the control groups (1.2% and 0%).

Reviewer	Reference	Study Design	Methods	Results
H, A, G, D&R	Khurshid R, Sheikh MA, Iqbal S. (2008) Health of people working/living in the vicinity of an oil-polluted beach near Karachi, Pakistan. East Mediterr Health J. 2008 Jan-Feb; 14(1):179-82. PMID: 18557466	Cross-sectional survey. Blood specimens obtained from 100 area residents and workers one month after spill; no control group.	Blood counts, liver and renal function tests. Hydrocarbon/organic content in seawater and sand samples.	Seawater had no traces of hydrocarbon content. Lymphocyte and eosinophil levels were slightly increased. About 11 people had raised serum glutamic pyruvic transaminase (SGPT) - not significant. Some alanine aminotransferase (ALT) elevations found.
H, A, G, E	Meo SA, Al-Drees AM, Meo IMU, Al- Saadi MM, Azeem MA (2008) Lung function in subjects exposed to crude oil spill into sea water. Mar Pollut Bull 2008;Jan,56(1):88-94. PMID: 18031764	Cross-sectional and longitudinal study of lung function one month after spill. 20 apparently healthy non-smoking male clean-up workers and 31 unexposed controls, one month and one year after the spill.	Spirometry.	Exposed subjects, vs. controls, had lower forced vital capacity (FVC) (3.70±0.12 vs. 4.67±0.11 litres, P<0.001), FEV at 1 second (FEV1) (2.82±0.17 vs. 3.58±0.07 litres, P<0.001); forced expiratory flow from 25% to 75% of vital capacity (FEF25–75%) (2.85±0.30 vs. 3.87±0.22 litres/sec, P = 0.02), and maximal voluntary ventilation (MVV) (105.85±6.72 vs 134.61±2.88 litres/min, P = 0.001) One year later, results for exposed workers were similar to results for controls.

Reviewer	Reference	Study Design	Methods	Results
D&R, L&N, E, L	Meo S, Al-Drees A, Rasheed S, Meo IM, et al. (2009a) Health complaints among subjects involved in oil clean-up operations during oil spillage from a Greek tanker "Tasman Spirit. Int J Occup Med Environ Health. 2009;22(2):143–8. PMID: 19546094	Cross-sectional study. Health complaints in 50 apparently healthy non-smoking male clean-up workers and 50 unexposed controls, one month and one year after the spill.	Standardized questionnaire, including a general introduction, family history, job description, smoking habit, tobacco chewing habit, and respiratory and general health complaints.	Subjects involved in oil clean-up operations had significantly higher rates of health complaints including cough (38%), runny nose (36%), eye irritation/redness (32%), sore throat (28%), headache (28%), nausea (24%) and general illness (18%), compared to their matched controls.
D&R, L	Meo S, Al-Drees A, Rasheed S, et al. (2009b) Effect of duration of exposure to polluted air environment on lung function in subjects exposed to crude oil spill into sea water. Int J Occup Med Environ Health 2009. 22(1):35–41. PMID: 19351614	Cross-sectional study of lung function in 31 apparently healthy, non-smoking, male clean-up workers and 31 controls.	Spirometry.	Subjects exposed to polluted air for periods longer than 15 days showed a significant reduction in Forced Vital Capacity (FVC), Forced Expiratory Volume in First Second (FEV1), Forced Expiratory Flow in 25-25% (FEF25-75%) and Maximal Voluntary Ventilation (MVV).

Reviewer	Reference	Study Design	Methods	Results
Hebei Spirit (2007) Taean, Korea, 10,900 t of crude oil.				
L, J	Kim BM[1], Park Ek, LeeAn SY, et al. (2009) BTEX exposure and its health effects in pregnant women following the Hebei Spirit oil spill. J Prev Med Public Health. 2009 Mar;42(2):96-103. PMID: 19349738	Cross-sectional, 2–3 months after the spill. Health effects of exposure to BTEX in 80 pregnant women from the Taean area.	Questionnaire survey to look for health effects. BTEX exposures were estimated using the CALPUFF dispersion model.	Pregnant women who lived near the accident site reported more symptoms of eye irritation and headache than those who lived farther from the site. Pregnant women exposed to higher ambient cumulative levels of Xylene were significantly more likely to report skin symptoms (odds ratio (OR) 8.01 95% CI=1.74-36.76) in the first day after the accident and significantly more likely to report abdominal pain (OR 3.86 95% CI=1.02-14.59 for ethylbenzene, OR 6.70 95% CI=1.82-24.62 for xylene) during the first through fourth days following the accident.
E, L, J	Lee S-M, Ha M, Kim E-J, et al. (2009) The effects of wearing protective devices among residents and volunteers participating in the cleanup of the Hebei Spirit oil spill. J Prev Med Public Health 2009 Mar;42(2):89–95. PMID: 19349737	Cross-sectional. Protective effects of wearing protective devices on exposure and symptoms among the 288 residents and 724 volunteers who participated in the cleanup.	Questionnaires about symptoms administered from the second to the sixth week following the accident. Spot urine samples were collected and analyzed for metabolites of four volatile organic compounds (VOCs), two polycyclic aromatic hydrocarbons (PAHs), and six heavy metals.	39- 98% of the residents and 62-98% of volunteers wore protective devices. Levels of fatigue and fever higher among residents not wearing masks than among those wearing masks (OR 4.5; 95% CI = 1.23-19.86). Urinary mercury levels significantly higher among residents not wearing work clothes or boots ($p<0.05$).

Reviewer	Reference	Study Design	Methods	Results
J	Lee CH, Kang YA, Chang KJ, et al. (2010) Acute health effects of the Hebei oil spill on the residents of Taean, Korea. J Prev Med Public Health. 2010 Mar;43(2):166-73. PMID: 20383050	Cross-sectional. 10 male and female adults from each of 10 heavy and 10 moderately oil-soaked seashore villages in Taean and the 10 lightly oil-soaked seashore villages in Seocheon.	Subjects interviewed using a structured questionnaire on characteristics of residents, clean-up activities, perception of oil hazard, depression and anxiety, physical symptoms.	Indexes of anxiety and depression higher in the heavy and moderately oil-soaked areas. Increased risks of headache, nausea, dizziness, fatigue, tingling of limb, hot flushing, sore throat, cough, runny nose, shortness of breath, itchy skin, rash, and sore eyes significant in the heavy and moderately oil-soaked areas.
E, L, J	Sim MS, Jo IJ, Song HG (2010) Acute health problems related to the operation mounted to clean the Hebei Spirit oil spill in Taean, Korea. Mar Pollut Bull. 2010; Jan;60(1):51–7. PMID: 19815241	Cross-sectional study Acute health problems in 846 clean-up workers who worked for 7-14 days.	Questionnaire on demographics, operation information, exposure to oil, and health status.	41.0% of workers experienced respiratory symptoms, 36.4% back pain, 29.3% headache, 27.9% neurovestibular symptoms, 17.7% eye symptoms, 5% skin lesions. Lack of protective suit associated with skin lesions, eye symptoms and neurovestibular symptoms. Lack of protective mask related to skin lesion, headache and neurovestibular symptoms. Number of days worked found to be related to increased risk of developing back pain and respiratory symptoms. Women showed increased risk of developing back pains, eye symptoms and neurovestibular symptoms.

Reviewer	Reference	Study Design	Methods	Results
D&R, E, L, J	Cheong HK, Ha M, Lee JS, et al. (2011) Hebei spirit oil spill exposure and subjective symptoms in residents participating in clean-up activities. Environ Health Toxicol. 2011;26:e2011 007. PMID: 22125768	Cross-sectional. Relationship between crude oil exposure and physical symptoms among residents participating in clean-up work. 288 residents of three villages who participated in clean-up work; 39 non-exposed inland residents. 2-6 and 8 weeks after spill.	Questionnaire regarding subjective physical symptoms (self-reported), sociodemographic characteristics and clean-up work. Urine of 154 of the respondents and 39 inland residents analyzed for metabolites of volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) and heavy metals.	Residents exposed to oil remnants through clean-up work showed associations between physical symptoms and the exposure levels defined in various ways, including days of work, degree of skin contamination. Most common subjective symptoms included eye irritation, musculoskeletal symptom, headache, fatigue/fever, nasal irritation, dermal irritation Urine analysis revealed elevated indicator of styrene exposure; elevated blood lead, mercury and cadmium levels observed.
D&R, E, L, J	Ha M, Kwon H, Cheong H-K, et al. (2012) Urinary metabolites before and after cleanup and subjective symptoms in volunteer participants in cleanup of the Hebei Spirit oil spill. Sci Total Environ. 2012 Jul 1;429:167–73. PMID: 22591993	Cross-sectional. Exposure status and acute health effects on 565 volunteers who participated in the cleanup.	Questionnaire regarding physical symptoms. Urinary metabolites of VOC and PAH measured before and after exposure in 105 university student volunteers.	Volunteers who participated for longer clean-up work reported an increase in physical symptoms including visual disturbance, nasal and bronchus irritation, headaches, heart palpitations, fatigue and fever, memory and cognitive disturbance, abdominal pain. Levels of t,t-muconic acid, mandelic acid, and 1-hydroxypyrene significantly higher in samples after cleanup than those measured before participation ($p<0.05$).

Reviewer	Reference	Study Design	Methods	Results
E, J	Gwack J, Lee JH, Kang YA, Chang K-J, Lee MS, Hong JY (2012) Acute health effects among military personnel participating in the cleanup of the Hebei Spirit oil spill, 2007, in Taean county, Korea. Osong Public Heal Res Perspect. 2012 Dec;3(4):206–12 PMID: 24159516	Cross-sectional survey of 2624 military personnel involved in clean-up for roughly five weeks, beginning immediately after the spill.	Self-administered questionnaire - self reported symptoms included six neurologic (headache, dizziness, nausea, fatigue, insomnia, hot flushing), five respiratory (sore throat, dry mouth, runny nose, cough, sputum), two dermatologic (itchiness, red skin), three ophthalmic s (sore eyes, red eyes, watery eyes), three general (general ache, back pain, febrile sense). Data on demographic factors, health behavioural factors (smoking history and usage PPE), occupational history (where and for how long individuals participated in cleanup).	Prevalence of subjective physical symptoms associated with duration of work, working in a highly contaminated area and inappropriate use of protective equipment.
D&R, E, L	Na JU, Sim MS, Jo IJ, Song HG (2012) The duration of acute health problems in people involved with the clean-up operation of the Hebei Spirit oil spill. Mar Pollut Bull. 2012 Jun;64(6):1246–51. PMID: 22491025	Cohort study (preceded by Sim et al.,2010) re-examining 442 clean-up workers one year after the spill.	Questionnaire on demographic information, risk factors, and the continuation and duration of any health symptoms.	Mean duration of symptoms: eye symptoms (9.7 months), headaches (8.4 months), skin symptoms (8.3 months), neurovestibular symptoms (6.9 months), back pain (1.8 months), respiratory symptoms (2.1 months). Remission of headaches had a negative correlation with female gender. Remission of eye symptoms a negative correlation with the total hours of daily participation in the clean-up operation.

Reviewer	Reference	Study Design	Methods	Results
E, L, J	Jung S-C, Kim K-M, Lee K-S, et al. (2013) Respiratory effects of the Hebei Spirit oil spill on children in Taean, Korea. Allergy Asthma Immunol Res. 2013 Nov;5(6):365–70 PMID: 24179682	Cross-sectional study of 436 children living within two km or more than two km of the contaminated coastline in heavily impacted Taean county, 1.5 years after the spill.	Modified International Study of Asthma and Allergies in Childhood questionnaire. Health examination, including a skin prick test, pulmonary function test, methacholine bronchial provocation test (MBPT).	Children living closer to the spill showed a significantly lower forced expiratory volume in one second (FEV1), an increased prevalence of 'asthma ever' (based on a questionnaire), and 'airway hyperresponsiveness' (based on the MBPT) than those who lived far from the oil spill area. Onset of wheezing after the oil spill significantly higher in children who lived close to the oil spill area than in those who lived far from the oil spill area.
L, J	Noh SR, Cheong HK, Ha M, Eom SY, Kim H, Choi YH, Paek D (2015) Oxidative stress biomarkers in long-term participants in clean-up work after the Hebei Spirit oil spill. Sci Total Environ. 2015 May 15;515-516:207-14. PMID: 25727518	Cross-sectional Relationship between oil-spill exposure and oxidative stress in 671residents living near the affected area. Data collected 14–23 months after the spill.	As surrogates for exposure: total duration of clean-up work and levels of urinary metabolites of polycyclic aromatic hydrocarbons (PAHs), 1-hydroxypyrene (1-OHP) and 2-naphthol (2-NAPH). Oxidative stress was measured using urinary levels of malondialdehyde (MDA) and 8-hydroxy-2'-deoxyguanosine (8-OHdG) as indicators of lipid peroxidation and oxidative DNA damage, respectively.	Levels of oxidative stress biomarkers were significantly increased with longer involvement in clean-up work over one year after the spill (MDA, p-trend<0.0001; 8-OHdG, p-trend <0.0001). As more time elapsed since the last involvement in clean-up, the total duration of clean-up work participation and levels of PAH metabolites (1-OHP and 2-NAPH), as well as levels of the oxidative stress biomarkers (MDA and 8-OHdG) decreased further. The level of 1-OHP had a significant positive correlation with the total duration of clean-up work involvement, with a higher level found in those who participated in clean-up for greater than100 days. Increasing levels of 1-OHP were significantly associated with increased MDA and 8-OHdG after adjusting for covariates, while the strength of association weakened as time passed since the last participation in clean-up work. The significance of the association was maintained for up to 12 months after the last clean-up work.

Reviewer	Reference	Study Design	Methods	Results
J	Kim JA, Noh SR, Cheong HK, et al. (2017) Urinary oxidative stress biomarkers among local residents measured 6years after the Hebei Spirit oil spill. Sci Total Environ. 2017 Feb 15;580:946-952. PMID: 27993476	Follow-up study on longer-term effects of the oil spill among 476 residents near the spill (near group) and 152 far from the spill (far group) six years after spill.	Questionnaire administered by trained interviewers or self-reporting demographic information (socioeconomic status, smoking and drinking behaviours, disease history, and duration of clean-up activities after the spill) collected. Levels of 8-hydroxy-2-deoxyguanosine (8-OHdG) and malondialdehyde (MDA) in 12-hour urine samples measured as indicators of oxidative DNA damage and lipid peroxidation, respectively. General linear model used for statistical analysis.	Urinary MDA and 8-OHdG levels measured from 'Near' group (geometric mean of 2.19µmol/g creatinine, and 5.41µg/g creatinine, respectively), higher than those of 'Far' group. Urinary 8-OHdG levels in the 'Near' group significantly higher than those of 'Far' after adjusting relevant covariates. Duration of clean-up activities showed a significant association with both urinary 8-OHdG and MDA levels. Six years after the oil spill, positive associations between oxidative stress biomarkers and surrogates of oil exposure were evident.
Deepwater Horizon (2010), Gulf of Mexico, spill size (t) 680,000				
L	Schaum J, Cohen M, Perry S, et al. (2010) Screening-level assessment of risks due to dioxin emissions from burning oil from the BP Deepwater Horizon Gulf of Mexico spill. Environ Sci Technol. 2010 Dec 15;44(24):9383-9. PMID: 21073188	Screening-level assessment of exposures and cancer risks posed by the dioxin emissions from in situ oil burns.	Upper estimates for the oil burn emission factor, modeled air and fish concentrations, and conservative exposure assumptions were used. U.S. EPA's AERMOD model used to estimate air concentrations in the immediate vicinity of the oil burns and NOAA's HYSPLIT model used to estimate more distant air concentrations and deposition rates.	The lifetime incremental cancer risks were estimated as 6 x 10^{-8} for inhalation by workers, 6 x 10^{-12} for inhalation by onshore residents, and 6 x10^{-8} for fish consumption by residents. For all scenarios, the risk estimates represent upper bounds and actual risks would be expected to be less.

Reviewer	Reference	Study Design	Methods	Results
D&R, E, L	D'Andrea MA, Reddy GK (2013) Health consequences among subjects involved in Gulf oil spill clean-up activities. Am J Med. 2013 Nov;126(11):966–74. PMID: 24050487	Cross-sectional retrospective study of 117 workers exposed to oil and dispersant for greater than three months; 130 controls.	Used medical charts, clinical data including white blood cell count, platelets count, hemoglobin, hematocrit, blood urea nitrogen, creatinine, alkaline phosphatase (ALP), aspartate amino transferase (AST), alanine amino transferase (ALT), and somatic symptom complaints by the subjects.	Major somatic symptoms: headaches (77%), shortness of breath (71%), skin rash (59%), chronic cough (51%), dizzy spills (51%), fatigue (50%), painful joints (49%), night sweats (41%), chest pain (38%). Platelet counts (× 10^3 per µL) significantly decreased in the exposed group compared with those in the control group (252.1 ± 51.8 vs 269.6 ± 77.3, P = .024). Hemoglobin (g per dL) and hematocrit (%) levels significantly increased among exposed subjects compared with the unexposed subjects (P = .000). Oil spill-exposed subjects had significantly higher levels of ALP (76.3 ± 21.3 vs 61.2 ± 26.9 IU/L, P = .000), AST (31.0 ± 26.3 vs 22.8 ± 11.8 IU/L, P = .004), and ALT (34.8 ± 26.6 vs 29.8 ± 27 IU/L, P = .054) compared with the unexposed subjects. Clean-up workers exposed to the oil spill and dispersant experienced significantly altered blood profiles, liver enzymes, and somatic symptoms.
D&R, L	D'Andrea MA, Reddy GK (2014) Health risks associated with crude oil spill exposure. Am J Med. 2014 Sep;127(9):886.e9 -13. PMID: 24859637	Cross-sectional. Hematological and liver function indices in 117 subjects who participated in clean-up operations.	Using medical charts, clinical data (including white blood cell [WBC] count, platelet count, hemoglobin, hematocrit, blood urea nitrogen [BUN] creatinine, alkaline phosphatase [ALP], aspartate amino transferase [AST], alanine amino transferase [ALT], and urinary phenol) were gathered for the subjects exposed to the Gulf oil spill and analyzed. Values were compared with the standardized normal range reference values.	Over 77% of subjects had WBC counts in the mid range (6-10× 10^3 per µL), while none of the subjects had the upper limit of the normal range (11× 10^3 per µL). A similar pattern was seen in the platelet counts and BUN levels among the oil spill-exposed subjects. Over 70% of the subjects had creatinine levels toward the upper limit of the normal range and 23% of subjects had creatinine levels above the upper limit of the normal range (>1.3 mg per dL). Hemoglobin and hematocrit levels were toward the upper limit of normal in more than two thirds of the subjects. AST and ALT levels above the upper limit of normal range (greater than 40 IU per L) were seen in 15% and 31% of subjects, respectively. Over 80% of subjects had urinary phenol levels higher than detectable levels (2 mg per L).

Reviewer	Reference	Study Design	Methods	Results
	Black JC, Welday JN, Buckley B, et al (2016) Risk Assessment for Children Exposed to Beach Sands Impacted by Oil Spill Chemicals. Int J Environ Res Public Health. 2016 Aug 27;13(9). PMID: 27618904	Determination of health risk to children who potentially contact beach sands impacted by oil spill chemicals.	EPA data collected during and immediately after the spill supplemented with measurements from beach sands and tar balls collected five years after the spill.	Metals in the sediments observed at similar levels between the two sampling periods; some differences observed for metals levels in tar balls. PAHs not observed five years later, but evidence of weathered-oil oxidative by-products. Comparing chemical concentration data to baseline soil risk levels, three metals (As, Ba, and V) and four PAHs (benzo[a]pyrene, benz[a]anthracene, benzo[b] fluoranthene, and dibenz[a,h]anthracene) were found to exceed guideline levels prompting a risk assessment. Health risks are extremely low, given the limitations of available data.
L	Peres LC, Trapido E, Rung AL, et al. (2016) The Deepwater Horizon Oil Spill and Physical Health among Adult Women in Southern Louisiana: The Women and Their Children's Health (WaTCH) Study. Environ Health Perspect. 2016 Aug;124(8):1208-13 PMID: 26794669	Cross-sectional. Association between exposure and physical health in 2126 women residing in southern Louisiana.	Telephone interview on frequency of 13 physical health symptoms. Exposure was characterized as physical/ environmental exposure and economic exposure.	High physical/environmental exposure significantly associated with all of the physical health symptoms, with the strongest associations for burning in nose, throat or lungs (OR = 4.73; 95% CI: 3.10, 7.22); sore throat (OR = 4.66; 95% CI: 2.89, 7.51); dizziness (OR = 4.21; 95% CI: 2.69, 6.58); and wheezing (OR = 4.20; 95% CI: 2.86, 6.17). Women who had high economic exposure were significantly more likely to report wheezing (OR = 1.92; 95% CI: 1.32, 2.79); headaches (OR = 1.81; 95% CI: 1.41, 2.58); watery, burning, itchy eyes (OR = 1.61; 95% CI: 1.20, 2.16); and stuffy, itchy, runny nose (OR = 1.56; 95% CI: 1.16, 2.08).

Reviewer	Reference	Study Design	Methods	Results
	Sammarco PW, Kolian SR, Warby RA, et al. (2016) Concentrations in human blood of petroleum hydrocarbons associated with the BP/Deepwater Horizon oil spill, Gulf of Mexico. Arch Toxicol. 2016 Apr;90(4):829-37. PMID: 25998020	Blood samples drawn 5-19 months after the spill had been capped from persons who experienced acute physiological and behavioural symptoms and consulted a physician.	Analyzed for aromatic compounds and alkanes. Compared with U.S. National Health and Nutritional Examination Survey/U.S. National Institute of Standards and Technology 95th percentiles.	Levels of m,p-xylene, toluene, ethylbenzene, benzene were not significantly different from 95th percentiles. o-xylene, and styrene, hexane, 3-methylpentane, 2-methyl-pentane, and iso-octane yielded equivocal results or significantly low concentrations.

Annex F: Epidemiological studies on mental health effects related to exposure to oil spills

Key to reviewers:

H = Ha M, Lee WJ, Lee S, Cheong HK (2008) A literature review on health effects of exposure to oil spill. J Prev Med Public Health. 2008 Sep;41(5):345-54. PMID: 18827503

A = Aguilera F, Méndez J, Pásaro E, Laffon B (2010) Review on the effects of exposure to spilled oils on human health. J Appl Toxicol. 2010 May;30(4):291-301. PMID: 20499335

L&N = Levy BS, Nassetta WJ (2011) The adverse health effects of oil spills: a review of the literature and a framework for medically evaluating exposed individuals. Int J Occup Environ Health. 2011 Apr-Jun;17(2):161-7. PMID: 21618948

G = Goldstein BD, Osofsky HJ, Lichtveld MY (2011) The Gulf oil spill. N Engl J Med. 2011 Apr 7;364(14):1334-48. PMID: 21470011

E = Eykelbosh, A (2014) Health Effects of Oil Spills and Implications for Public Health Planning and Research, National Collaborating Centre for Environmental Health, Vancouver Coastal Health. [http://www.ncceh.ca/sites/default/files/Health_Effects_Oil_Spills_Nov_2014.pdf]

D&R = D'Andrea MA, Reddy GK (2014) Crude oil spill exposure and human health risks. J Occup Environ Med. 2014 Oct;56(10):1029-41 PMID: 25285825

L = Laffon B, Pásaro E, Valdiglesias V (2016) Effects of exposure to oil spills on human health: Updated review. J Toxicol Environ Health B Crit Rev. 2016;19(3-4):105-28. PMID: 27221976

J = Jung D, Kim JA, Park MS, Yim UH, Choi K. (2017) Human health and ecological assessment programs for Hebei Spirit oil spill accident of 2007: Status, lessons, and future challenges. Chemosphere. 2017 ;173:180-189. PMID: 28110007

Reviewer	Reference	Study Design	Methods	Results
Exxon Valdez (14 March 1989) Bligh reef, Prince William, Alaska, USA; spill size (t) 37,000.				
E	Picou J, Gill D (1992) Disruption and stress in an Alaskan fishing community: Initial and continuing impacts of the *Exxon Valdez* oil spill. Organ Environ. 1992;6(3):235–57.	Cohort study at five and 18 months after the spill.	118 residents of Cordova, AK (impacted community) and 73 residents of Petersburg AK (non-impacted community).	Impact community shows significant increase in social disruption and psychological stress compared to the control community at five months after the spill; effects lessen at 18 months, but remain elevated.

Reviewer	Reference	Study Design	Methods	Results
H, A, G, E, D&R	Palinkas L, Russell J, Downs M, Petterson J (1992) Ethnic differences in stress, coping, and depressive symptoms after the *Exxon Valdez* oil spill. J Nerv Ment Dis. 1992 May; 180(5):287–95. PMID: 1583472	Cross section study with face-to-face interviews to examine ethnic differences in both the association between depressive symptomatology and exposure to the *Exxon Valdez* oil spill and subsequent clean-up efforts, and in the role of family support as a moderator of exposure to disaster.	599 people (188 indigenous; 371Euro-Americans) living in 11 impacted and two non-impacted Alaskan communities, approximately one year after the spill. Used Center for Epidemiological Studies Depression (CES-D) Scale.	Level of exposure significantly associated with mean CES-D scores in both indigenous ($P<0.05$) and Euro-Americans ($P<0.01$). Both groups also reported significant declines in traditional relations with increasing levels of exposure (p less than .001). Indigenous had a significantly higher mean Exposure Index score than Euro-Americans and were more likely to report working on clean-up activities, damage to commercial fisheries, and effects of the spill on subsistence activities. Depressive symptomatology was associated with reported participation in clean-up activities and other forms of contact with the oil in indigenous and with reported damage to commercial fisheries, use of affected areas, and residence in a community in geographic proximity to the spill in Euro-Americans. Perceived family support was not directly associated with depressive symptoms in either group, but did serve to buffer the effects of exposure on depressive symptoms in Euro-Americans.
H, A, G, E, D&R	Palinkas LA, Petterson JS, Russell J, Downs MA (1993) Community patterns of psychiatric disorders after the *Exxon Valdez* oil spill. Am J Psychiatry. 1993 Oct;150(10):1517-23. PMID: 8379557	Cross section study with face-to-face interviews of 593 people living in 11 impacted and 2 non-impacted Alaskan communities, approximately one year after the spill.	437 exposed workers and 162 controls. Used Center for Epidemiologic Studies Depression (CES-D) Scale to access depression and Questions from the National Institute of Mental Health Diagnostic Interview Schedule to access anxiety and PTSD.	Most exposed group was more likely than controls to have generalized anxiety disorder (GAD) (odds ratio, 3.73; 95% CI, 1.99–6.97), post-traumatic stress disorder (PTSD), (odds ratio, 2.63; 95% CI, 1.22–5.66), and depression (defined as CES-D score greater than or equal to18; odds ratio, 2.13; 95% CI, 1.01–4.50). Women were significantly more vulnerable than men regarding all three measures. Indigenous and younger men had more evidence of depression than other subgroups.

Reviewer	Reference	Study Design	Methods	Results
E	Palinkas L, Downs M, Petterson J, Russell J (1993) Social, cultural, and psychological impacts of the *Exxon Valdez* oil spill. Hum Organ. 1993;52(1):1–13.	Cross section study with face-to-face interviews. 594 people living in 11 impacted and two non-impacted Alaskan communities, approximately one year after the spill.	Questions from the National Institute of Mental Health Diagnostic Interview Schedule used to assess symptoms of generalized anxiety disorder (GAD) and PTSD. The Center for Epidemiologic Studies Depression (CES-D) Scale used to assess levels of depressive symptoms.	Marked spill impact-related declines in social relationships and engagement in subsistence activities, and increases perceived physical health and mental disorders.
A, G, D&R	Gill D, Picou J (1998) Technological disaster and chronic community stress. Soc. Natur. Resour. 1998 11: 795-815.	Longitudinal study over four years of stress and social effects in affected community (Cordova, AK) vs. control community (Petersburg, AK).	Sample sizes: Cordova — 118 in 1989, 228 in 1991, and 41 in 1992 Petersburg — 73 in 1989, 102 in 1991, and 41 in 1992 Questionnaires on out-migration desires, expectations and social disruption. Score on Impact of Events Scale (of psychological stress).	Data revealed the chronic nature of stress. Event-related psychological stress diminished with time, although three years after the spill, 50% of Cordova residents were still classified as having a high level of social disruption and more likely than controls to have a desire or expectation to migrate.
E, D&R	Arata CM, Picou JS, Johnson GD, McNally TS (2000) Coping with technological disaster: an application of the conservation of resources model to the *Exxon Valdez* oil spill. J Trauma Stress. 2000 Jan;13(1):23–39. PMID: 10761172	Mail in survey regarding current mental health functioning approx. six years after spill.	125 fisherman from Cordova, AK. Modified Coping Strategies Scales, Symptom Checklist 90-R.	Clinically significant depression and anxiety, PTSD symptoms – related to resource loss, breakdown of kin and non-kin relationships, deterioration of physical health, time spent in litigation, income loss.

Reviewer	Reference	Study Design	Methods	Results
H, A, G	Palinkas LA, Petterson JS, Russell J, Downs MA (2004) Ethnic differences in symptoms of post-traumatic stress after the *Exxon Valdez* oil spill. Prehosp Disaster Med 2014 Jan-Mar 19: 102–112. PMID: 15453167	Cross-sectional study one year after spill of PTSD symptoms.	188 indigenous people; 371 Euro-Americans. Modified form of Version III of the Diagnostic Interview Schedule scores (DIS).	High levels of social disruption associated with PTSD one year after spill in both ethnic groups. Low family support, participation in clean-up activities, and a decline in subsistence activities significantly associated with PTSD only in indigenous people.
E	Picou J, Marshall B, Gill D (2004) Disaster, Litigation, and the Corrosive Community. Soc Forces. 2004;82(4):1493–522.	Cohort study examining residents of Cordova, Alaska, 3.5 years after the spill.		Perceived damage to the community and degree of psychological stress associated with loss of trust, community attachment, work disruption, litigation stress, and perceived oil spill risk.

Reviewer	Reference	Study Design	Methods	Results
G	Picou JS, Formichella C, Marshall BK, Arata C (2009) Community impacts of the *Exxon Valdez* oil spill: a synthesis and elaboration of social science research. In: Braund SR, Kruse J, eds. Synthesis: three decades of research on socioeconomic effects related to offshore petroleum development in coastal Anchorage, AK. Stephen R. Braund, May 2009:279-307. (MMS OCS study no. 2009-006.)	Longitudinal study of residents of exposed community (Cordova, AK).	223 residents in 1991, 154 in 1992, and 96 in 2000. Intrusive stress factors.	In 2000, greater than 95% of respondents reported that the community had not recovered. Litigant status predicted the degree of spill-related stress.
Sea Empress (15 February 1996) Milford Haven, 73,000 tons of crude oil released near a highly populated area, with strong odours detectable in the area.				
H,A, L&N, G, E, D&R	Lyons R, Temple J, Evans D (1999) Acute health effects of the Sea Empress oil spill. J Epidemiol Community Health. 1999;53:306–10. PMID: 10396538	Retrospective cohort study; seven weeks after spill asking about symptoms during the first four weeks after the spill. 539 exposed residents, 550 controls in towns on the coast of Wales	Postal questionnaire including demographic details, a symptom checklist, beliefs about health effects of oil. Hospital Anxiety and Depression (HAD) and SF-36 mental health scales.	Total of 23% of exposed residents believed oil spill to have affected their health, vs. 2% of controls. Residence in exposed community associated with higher anxiety scores ($P = 0.04$) and depression scores ($P = 0.049$) and lower SF-36 mental health scores ($P = 0.002$).

Reviewer	Reference	Study Design	Methods	Results
H, A, E, D&R	Gallacher J, Bronstering K, Palmer S, Fone D, Lyons R (2007) Symptomatology attributable to psychological exposure to a chemical incident: a natural experiment. J Epidemiol Community Health. 2007 Jun;61(6):506–12. PMID: 17496259	Cross-sectional study seven weeks after spill, focused on acute psychological symptoms attributable to exposure vs. perception of exposure.	Postal questionnaires of acute toxic and non-toxic symptoms sent to a random sample of 1585 men and women aged 18–65 year in four exposed coastal towns and two control coastal towns; 1089 (69%) responded; 539 exposed residents and 550 controls. Scored on Hospital Anxiety and Depression Scale.	Reporting of toxicity symptoms and psychological symptoms was highly associated with perception of exposure than proximity to spill. Perceived health and financial risks associated with anxiety and depression. Perceived environmental risk associated with anxiety.
Prestige (19 November 2002) Galicia, Spain; 63,000 tons of fuel oil (no 6) were released, rapidly at first and more slowly over a period of months; more than 100,000 people were involved in the response.				
H, A, G, E, D&R	Carrasco JM, Pérez-Gómez B, García-Mendizábal MJ, et al. (2007) Health-related quality of life and mental health in the medium-term aftermath of the Prestige oil spill in Galiza (Spain): a cross-sectional study. BMC Public Health. 2007 Jan;7(1):245. PMID: 17875207	Cross-sectional study of 16-month period after spill, focusing on health-related quality of life (HRQoL) and mental health among 1350 coastal residents in seven towns vs. 1350 controls residing in seven inland towns.	Questionnaires of perceived social support and mental health focusing on exposure conditions, acute health problems, use of protective material and health-protection information receive. SF-36, General Health Questionnaire (GHQ-28), Hospital Anxiety and Depression Scale (HADS), and Goldberg Anxiety and Depression Scale (GADS).	For residential exposure, the SF-36 showed coastal residents as having a lower likelihood of registering suboptimal HRQoL values in physical functioning (OR:0.69; 95%CI:0.54–0.89) and bodily pain (OR:0.74; 95%CI:0.62– 0.91), and a higher frequency of suboptimal scores in mental health (OR:1.28; 95%CI:1.02–1.58).

Reviewer	Reference	Study Design	Methods	Results
A, G, E	Sabucedo JM, Arce C, Ferraces MJ, Merino H, Durán M (2009) Psychological impact of the Prestige catastrophe. Int J Clin Heal Psychol. Asociación Española de Psicología Conductual; 2009;9(1):105–16.	Cross-sectional study one year after the spill of psychological effect on 938 fishermen and control subjects from 23 coastal locations from three zones according to their proximity to the location of the spill.	Questionnaires on perceived involvement and social support, satisfaction with the financial aid received and social relationships. Modified version of the CRI-ADULT coping response inventory. Simplified version of the Symptom Checklist (SCL-36).	Affected residents with great social support, high satisfaction with economic aid, or evasive coping strategies had better mental health scores than other affected residents and even than controls. No relevant clinical symptoms were found among residents.
G, E, L	Sabucedo JM, Arce C, Senra C, Seoane G, Vázquez I (2010) Symptomatic profile and health-related quality of life of persons affected by the Prestige catastrophe. Disasters. 2010 Jul;34(3):809–20. PMID: 20345463	Cross-sectional study of 926 fishermen and control subjects from the same community, one year after the spill. Impact on mental health and perception of physical health and functional capacity.	Questionnaire administered by psychologists. Symptom Checklist (SCL-36) scale for mental health symptoms and four subscales from the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) (General Health, Physical Role, Emotional Role, and Social Function) for physical health and functional capability.	Individuals with higher degrees of exposure or residing in areas closest to the spill show lower levels of mental health. Residents closer to spill had lower perception of physical health and functional capacity. Fishermen had more somatization than nonfishermen. Women were more affected than men.
L	Pérez-Pereira M, Tinajero C, Rodríguez MS, Peralbo M, Sabucedo JM (2012) Academic effects of the Prestige oil spill disaster. Spanish J Psychol. 2012 Nov:15(3):1055–68. PMID: 23156914	Cross-sectional. Effect on academic achievement and classroom behaviour of106 preschool children (ages 5–6 years), 177 school-aged children (ages 10–11 years), 147 adolescents (ages 15–16 years) living in three differently affected areas.	Academic qualifications in school records, Classroom Behavior Inventory (CBI) questionnaire reported by teachers, Coping Scale for Children and Youth (CSCY).	No general effect of the disaster on the preschool children. Primary school-aged children showed higher hostility to others after the spill than before. Higher effect on adolescents when compared to other groups – lower academic scores, higher intelligent behaviour, extraversion, and independence after the spill than before. Academic achievement, but not schoolroom behaviour, influenced by coping strategies and family characteristics.

Reviewer	Reference	Study Design	Methods	Results
Hebei Spirit (2007) Taean, Korea, 10,900 t of crude oil.				
L&N, L, D&R	Song M, Hong YC, Cheong HK, Ha M, Kwon H, Ha EH, Choi Y, Jeong WC, Hur J, Lee SM, Kim EJ (2009) Psychological health in residents participating in clean-up works of Hebei Spirit oil spill. J Prev Med Public Health. 2009 Mar;42(2):82-8. PMID: 19349736.	Cross-sectional. Psychological health of the 71 residents of Taean during the oil spill cleanup conducted eight weeks after spill. Data from the existing studies that may represent a general Korean group used as a comparison group.	Questionnaires: PWI (Psychological Well-being Index) scale for psychosocial distress, the CES-D (Center for Epidemiologic Studies-Depression) scale for depressive symptoms, and a questionnaire created to assess suicidal impulses.	64.2% of study group showed an overall prevalence of high-risk psychosocial distress 77.6% of respondents had scores on the CES-D Scale above 16 and 62.7% above 21. 18.3% of respondents categorized as having suicidal impulses. When compared with unexposed groups, the residents of Taean were 6.5 times as likely to have high stress and 9.4-9.7 times as likely to be depressed. No significant difference in the rate of suicidal impulse found between the residents of Taean and the general population. Factors associated with high stress, depression, and suicidal impulses were age, a change in income, educational level, number of days working on the cleanup, and positive responses to questions about "affected daily activity" and "hospital visit due to work on cleanup."
L&N, L, J, D&R	Lee CH, Kang YA, Chang KJ, et al. (2010) Acute health effects of the Hebei oil spill on the residents of Taean, Korea. J Preven Med Pub Health. 2010; Mar43(2):166-173. PMID: 20383050	Cross-sectional. Acute health effects in residents from seashore villages of a heavily and moderately oil-soaked area and a lightly oil-soaked area (10 villages from each area, 10 adults from each village, both genders).	Questionnaire on the characteristics of residents, the clean-up activities, the perception of oil hazard, depression (CES-D) and anxiety (State-Trait Anxiety Inventory (STAI-X-1)), and the physical symptoms.	Residents of the more highly contaminated were more likely to be engaged in clean-up activities and having a greater chance of exposure to oil. Indexes of anxiety and depression were higher in the heavily and moderately oil-soaked areas.

Reviewer	Reference	Study Design	Methods	Results
E, L, J, D&R	Ha M, Jeong W-C, Lim M, Kwon H, Choi Y, Yoo S-J, et al. (2013) Children's Mental Health in the Area Affected by the Hebei Spirit Oil Spill Accident. Environ Health Toxicol. 2013 Aug 30; 28:e2013010. PMID: 24010065	Cross-sectional study of 1,361 students attending schools at various distances from the impacted coastline. Surveys at eight weeks and four to five months after spill.	Questionnaire using Korean versions of the Children's Depression Inventory and State Anxiety Inventory for Children.	Children with the closest distance (in the fourth quartile) to the school from the contaminated coastline showed a significantly higher symptom risk of depression compared to those with the farthest distance (first quartile) (odds ratio, 2.73; 95% confidence interval, 1.40-5.33). No significant association between anxiety symptoms and distance.
L	Kim Y-M, Park J-H, Choi K, Noh SR, Choi Y-H, Cheong H-K (2013) Burden of disease attributable to the Hebei Spirit oil spill in Taean, Korea. BMJ Open. 2013 Sep 20;3(9):e003334. PMID: 24056482	Cross-sectional, 1.5 years after the spill. Assess burden of disease (BOD), including physical and mental diseases, in 10,171 residents (male 4,354; female 5,817), living in contaminated coastal area.	Questionnaires on exposure and medical problems, and to assess psychological health and asthma. Physical and laboratory examinations of respiratory, cardiovascular, neurological, and psychological systems. Disability adjusted life-year (DALY) method used to measure BOD.	Years lived with disability (YLD) attributable to the oil spill estimated to be 14 724 DALYs (male 7425 DALYs; female 7299 DALYs) for the year 2008. The YLD of mental diseases including post-traumatic stress disorder (PTSD) and depression for men was higher than that for women. The YLD for women was higher in asthma and allergies (rhinitis, dermatitis, conjunctivitis) than that for men. The effects of asthma and allergies were greatest for people in their 40s, with the burden of mental illness being the greatest for those in their 20s. Proximity to the spill site associated with increased BOD.

Reviewer	Reference	Study Design	Methods	Results
L, J	Choi KH, Lim MH, Ha M, et al. (2015) Psychological Vulnerability of Residents of Communities Affected by the Hebei Spirit Oil Spill. Disaster Med Public Health Prep. 2016 Feb 10(1)5:1-8. PMID: 26046599	Cross-sectional. Prevalence of psychological symptoms in 993 residents of communities affected by the spill.	Scales for PTSD (PDS), Center for Epidemiologic Studies-Depression (CES-D), suicidal ideation (SSI) and anxiety Symptom Checklist-90-Revision (SCL-90-R).	Symptom prevalence of PTS (19.5%), depression (22.0%), suicidal ideation (2.3%), anxiety (4.2%). Symptoms were higher in female, older, less educated, lower family income residents. People with fishery or related occupations compared to those with unrelated livelihoods and people residing in the vicinity of the oil band in the contaminated coastline showed additively increased symptom risks of PTS. Risk of suicidal ideation predominantly increased in people with fishery or related occupations compared with those with unrelated livelihoods.

Reviewer	Reference	Study Design	Methods	Results
Deepwater Horizon, Gulf of Mexico (20 April 2010).				
G, E, L	Abramson D, Redlener I, Stehling-Ariza T, Sury J, Banister A, Park Y (2010) Impact on children and families of the deepwater horizon oil spill: preliminary findings of the coastal population impact study. National Center for Disaster Preparedness. [https://academiccommons.columbia.edu/catalog/ac:128195]	1,203 adults who lived within approximately ten miles of the Gulf Coast. 481 households in Louisiana, 722 households in Mississippi covered. 518 households had one or more children – one child from each household included in survey. Questionnaire and the telephone interview using trained interviewers between July 19 and July 25, 2010.	Asked about: **posure:** direct exposure to oil spill, **ects on children:** immediate and rceived long-term physical and ental health effects of the oil spill on ildren and on adults and on onomic effects of the spill that have en felt by the coastal population, **cisions:** how the oil spill has begun to ape decisions faced by coastal idents (daily decisions - where ildren can play, whether local afood is safe to eat and projected cisions about whether or not people nk they will have to move, **st:** which public officials are most sted to provide accurate and reliable ormation, and who is perceived to ve been most (or least) responsive to oil spill crisis.	er 40% of the population living within ten miles of coast had experienced some direct exposure the oil spill. er one-third of parents reported that their ildren had experienced either physical symptoms mental health distress as a consequence of the spill. e in five households has seen their income crease as a result of the oil spill, 8% have lost jobs. ly 5% of coastal residents reported having ceived any cash or gift cards from BP, although er 15% believe they may be eligible for mpensation from BP for health consequences of spill. er 25% of coastal residents think they may have move from the area because of the oil spill.

Reviewer	Reference	Study Design	Methods	Results
E, L	**Grattan** LM, **Roberts** S, Mahan WT Jr, McLaughlin PK, Otwell WS, Morris JG Jr (2011) The early psychological impacts of the Deepwater Horizon oil spill on Florida and Alabama communities. Environ Health Perspect. 2011 Jun;119(6):838-43. PMID: 21330230	Cross-sectional. Standardized assessments of psychological distress (mood, anxiety), coping, resilience, neurocognition, and perceived risk on residents of fishing communities indirectly impacted (n = 71, Franklin County, Florida) or directly exposed (n = 23, Baldwin County, Alabama) to coastal oil.	Findings for participants who reported income stability (n = 47) versus spill-related income loss (n = 47) compared. Standard interview and formal neuropsychological, psychosocial, and risk perception measures (modified Boston Occupational and Environmental Neurology Questionnaire (BOENQ) and Brief Michigan Alcohol Screening Test (BMAST)questionnaires, WHO Neurobehavioral Core Test Battery, Profile of Mood States (POMS) test, Brief COPE questionnaire, CD-RISC short form, Health and Coastal Environment Questionnaire-V (HCEQ-V) questionnaire.	No significant differences between community groups were found. Residents of both communities displayed clinically significant depression and anxiety. Relative to those with stable incomes, participants with spill-related income loss had significantly worse scores on anxiety, depression, fatigue, confusion, and total mood disturbance scales; had higher rates of depression; were less resilient; and were more likely to use behavioural disengagement as a coping strategy.
L	Osofsky HJ, Palinkas LA, Galloway JM. (2010) Mental health effects of the gulf oil spill. Disaster Med Public Health Prep. 2010 Dec;4(4):273-6 PMID: 21149227	Cross-sectional. Effects on mental health of 452 residents of areas affected by the spill.	Telephone and face-to-face interviews assessing concerns and direct impact (also from Hurricane Katrina). Modified version of the Sheehan Disability Scale, CD-RISC (Connor-Davidson Resilience Scale), WHO Quality of Life scale (WHO-QoL), K6, and Posttramautic Check List for Civilians (PCL-C) scales.	Greatest effect on mental health was related to the extent of disruption to participant's lives, work, family, and social engagement, with increased symptoms of anxiety, depression, and post-traumatic stress.

Reviewer	Reference	Study Design	Methods	Results
E, D&R	Osofsky HJ, Osofsky JD, Hansel TC (2011) Deepwater Horizon oil spill: mental health effects on residents in heavily affected areas. *Disaster Med Public Health Prep.* 2011 Dec;5(4):280–286. PMID: 22146666	Cross-sectional survey of 452 residents of four Louisiana parishes 4-8 months after the spill. 67.6% of residents women, 65.3% aged 41 years or older, 65.5% married/cohabitating, 77.9% white, 65.9% with annual income less than $40,000, 15.7% working in occupations affected by spill.	Telephone and face-to-face interviews assessing concerns and direct impact (also from Hurricane Katrina). Modified version of the Sheehan Disability Scale, CD-RISC (Connor-Davidson Resilience Scale), WHO Quality of Life scale (WHO-QoL), K6, and Posttramautic Check List for Civilians (PCL-C) scales.	Greatest effect on mental health related to the extent of disruption to participants' lives, work, family, and social engagement, with increased symptoms of anxiety, depression, and post-traumatic stress. Losses from Hurricane Katrina were highly associated with negative mental health outcomes. Ability to rebound after adversity and place satisfaction were highly associated with better mental health outcomes.
E, L	Gill DA, Picou SJ, Ritchie LA (2012) The *Exxon Valdez* and BP Oil Spills: A Comparison of Initial Social and Psychological Impacts. Am Behav Sci Jan 2012 56: 3-23,	Cross-sectional. Comparison of the social and mental health impacts in residents of south Mobile County Alabama (N = 412), and Cordova (Alaska), exposed to *Exxon Valdez* oil spill. Data collected five months after each event.	Telephone survey of Alabama residents included a standardized measure of psychological stress (Impact of Event Scale), as well as measures of ties to resources, resource loss, perceptions of recreancy, risk perceptions, and demographic characteristics.	Data on total impact, intrusive stress, and avoidance behaviour in Gulf coast communities five months after the spill show very similar results to the same data collected in Cordova, Alaska, five months after the *Exxon Valdez* spill, suggesting the possibility of similar long-term effects. Event-related psychological stress among residents of south Mobile County was relatively high and similar to that of residents of Cordova. Strongest predictors of stress were family health concerns, commercial ties to renewable resources, and concern about economic future, economic loss, and exposure to the oil.

Reviewer	Reference	Study Design	Methods	Results
E, L	Lee MR, Blanchard TC (2011) Community Attachment and Negative Affective States in the Context of the BP Deepwater Horizon Disaster. Am Behav Sci. 2011 Oct 3;56(1):24–47. 63	Cross-sectional telephone survey of 935 residents of three Louisiana parishes, two months after the spill while the oil was still flowing.	Survey with demographic, health-related, and community attachment questions.	Negative affective state *increases* with greater community attachment, pre-spill stress, routine worrying, and being involved in fishing Negative affective state decreases among the retired and those employed full-time. High school graduates have a lower level of negative affect than individuals with a bachelor's or graduate degree.
E, L, D&R	Buttke D, Vagi S, Bayleyegn T, et al. (2012) Mental health needs assessment after the Gulf Coast **oil spill**-Alabama and Mississippi, 2010. Prehosp Disaster Med. 2012 Oct;27(5):401-8. PMID: 22985680	Cross-sectional survey to assess the mental health status of 469 coastal residents in three counties in Alabama four months after the oil spill and in the Gulf Coast counties in Mississippi 5.5 months after the oil spill.	Questionnaire to evaluate physical symptoms, quality of life, mental health, social context and exposure.	15.4 - 24.5% of the respondents reported depressive symptoms, with 21.4-31.5% reporting symptoms consistent with an anxiety disorder, and 16.3-22.8% reporting greater than14 mentally unhealthy days within the past 30 days. More negative quality of life indicators and negative social context outcomes than in the state's Behavioral Risk Factor Surveillance System (BRFSS) survey. Of all households 32.1% - 35.7% reported decreased income since the spill; 35.5-38.2% reported having been exposed to oil.

Reviewer	Reference	Study Design	Methods	Results
E, D&R, L	Buttke D, Vagi S, Schnall A, et al. (2012) Community Assessment for Public Health Emergency Response (CASPER) one year following the Gulf Coast oil spill: Alabama and Mississippi, 2011. Prehosp Disaster Med. 2012 Dec;27(6):496-502. PMID: 23010443.	Cross-sectional survey of Gulf Coastal communities in Alabama and Mississippi one year after the spill.	Questionnaire including the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System (BRFSS) – standardized behavioural health questions on quality of life, depression, anxiety, and social context.	Compared to previous cross-sectional survey (Buttke et al. (2012a), re-sampled households show slightly overall improvement in mental health indicators, but still worse than pre-spill state baseline. Respondents reporting decreased income following the oil spill were more likely to show poor mental health.
L	Werner, D, Locke C (2012) Experiences of chronic stress one year after the Gulf **oil spill.** Int J Emerg Ment Health 2012 14(4):239–45. PMID: 23980488	Mental health effects on two Gulf Coast communities one year after the spill, reported by 17 mental health clinicians employed by Project Rebound and four counselors from two school districts on the Gulf Coast.	Interviews related to mental health response and recovery in the communities, to identify common stressors (family disruptions, job loss or change in economic conditions, financial pressures, and bureaucratic hassles) that emerge from the disaster.	One year post-spill, clinicians reported that families were still experiencing disruption. Families and communities reported increased financial pressures due to the loss of economic opportunities and life-long careers. Bureaucratic hassles in applying to Gulf Coast Claims Facility and receiving appropriate payment were also reported. Individuals who have never needed to ask for help are now seeking services.

Reviewer	Reference	Study Design	Methods	Results
E	Cope MR, Slack T, Blanchard TC, Lee MR (2013) Does time heal all wounds? Community attachment, natural resource employment, and health impacts in the wake of the Deepwater Horizon disaster. Soc Sci Res. 2013 May;42(3):872-81. PMID: 23522000	Cross-sectional telephone survey of residents of three Louisiana parishes, two, six, and 12 months after the spill.	Louisiana Community Oil Spill Survey to examine the impacts of the disaster on the mental and physical health of spill affected residents in coastal Louisiana, with a special focus on the influence of community attachment and natural resource employment.	Mental and physical health impacts decrease over time and with greater community attachment. Impacts increase with involvement in fishing, unemployment, long-time residence, female gender, less education, and Cajun ethnicity.
L	Locke C and Werner D (2013) Stigma of help-seeking behaviour following the Deepwater Horizon oil spill. Contemporary Rural Social Work 2013 5:17–41.	Cross-sectional. Delivery and utilization of mental health services, and role of stigma related to help seeking behaviour, on two Gulf Coast communities one year after the spill reported by17 mental health clinicians employed by Project Rebound and four counselors from two school districts on the Gulf Coast.	Interviews with questions for defining the disaster and recovery efforts, identification of people in need and service delivery, and challenges and needs for future disasters.	Clinicians experienced a number of stigma-related barriers to delivering services including self-stigma, public stigma, and cultural implications of seeking and receiving aid. Clinicians and school counselors found that the children were a vehicle to identify and provide services to families in need, which negated some of the initial stigma related to help-seeking behaviour. Media exposure was associated with persistent hyperarousal.

Reviewer	Reference	Study Design	Methods	Results
E, L, D&R	Morris JG, Grattan LM, Mayer BM, Blackburn JK (2013) Psychological responses and resilience of people and communities impacted by the Deepwater Horizon oil spill. Trans Am Clin Climatol Assoc. 2013;124:191–201. PMID: 23874022	Cohort study (preceded by Grattan et al., 2011) following 93 residents in two communities Florida and Louisiana for one year.	Background and history questionnaire as well as the Profile of Mood States (POMD) (anxiety, depression), Impact of Event Scale (post-traumatic stress symptoms: avoidance, intrusion, and hyperarousal), the Connor-Davidson Resilience Scale (CD-RISC) (self-reported resilience), within the context of a broader psychological and neuro-psychological examination.	A year after the spill, there was no significant change in levels of anxiety or depression in the cohort assessed. Income loss continued to be associated with higher levels of psychopathology (anxiety, depression, mood disturbance, loss of vigor); findings were not associated with age, gender, education, or psychiatric history.
E	Ngo D, Gibbons JL, Scire G, Le D (2014) Mental Health Needs in Vietnamese American Communities Affected by the Gulf Oil Spill. Psychology. Scientific Research Publishing; 2014 Feb 26;05(02):109–15.	Focus groups with Vietnamese coastal residents Alabama, Louisiana, and Mississippi to assess the impact of the oil spill disaster in the areas of economic hardship, family functioning, and behavioural and mental health issues. Sixty Vietnamese speaking individuals (65% females) with an age range from 28 - 65 years and average of eight years of education.	Approximately 77% had worked in the seafood industry. About 92% indicated that they spoke English "not very well". Data checked by Vietnamese- speaking researcher.	Nearly all participants reported being negatively affected by the oil spill disaster - loss of income (59%), loss of employment (27%), and inability to pay bills (12%). High levels of stress, anxiety and depression, as well as an increase in behavioural problems reported. None of the participants claimed to know where or how to seek help for mental health problems.

Reviewer	Reference	Study Design	Methods	Results
	Drescher CF, Schulenberg SE, Smith CV (2014) The **Deepwater Horizon Oil Spill** and the Mississippi Gulf Coast: Mental health in the context of a technological disaster. Am J Orthopsychiatry. 2014 Mar;84(2):142-51. PMID: 24826930	Clinical sample of 1,119 adults receiving mental health services in the coastal counties of Mississippi after the Gulf **Oil Spill.**	Levels of clinical symptoms reported on the Depression Anxiety Stress Scales (DASS-21) and PTSD Checklist (PCL-S) examined in relation to other domains of functioning potentially affected by the **spill** (finances, social relationships, and physical health).	Chronic problems in living related to the Gulf **Oil Spill** significantly associated with higher levels of psychological distress, although the pattern differed somewhat for persons living above and below the poverty line, with lower income individuals reporting a higher level of overall distress.
	Gould DW, Teich JL, Pemberton MR, Pierannunzi C, Larson S (2015) Behavioral health in the gulf coast region following the Deepwater Horizon oil spill: findings from two federal surveys. J Behav Health Serv Res. 2015 Jan;42(1):6-22. PMID: 25339594	Two large-scale, population-based surveys conducted by Substance Abuse and Mental Health Services Administration (SAMHSA) and Centers for Disease Control and Prevention (CDC) in the Gulf Coast region following the 2010 Deepwater Horizon oil spill, to measure the prevalence of mental and substance use disorders, chronic health conditions, and utilization of behavioural health services.	2011 National Survey on Drug Use and Health (NSDUH) Gulf Coast Oversample (GCO) and questions on anxiety and depression from Patient Health Questionnaire (PHQ-8) and tne seven-item Generalized Anxiety Disorder (GAD-7) questionnaire. 32 counties most affected in Alabama, Florida, Louisiana, and Mississippi sampled.	Although many area residents undoubtedly experienced increased levels of anxiety and stress following the **spill**, findings suggest only modest or minimal changes in behavioural health at the aggregate level before and after the **spill.** Resources mobilized to reduce the economic and behavioural health impacts of the **spill** on coastal residents-including compensation for lost income from BP and increases in available mental health services may have resulted in a reduction in potential mental health problems. Limitations of study discussed.

Reviewer	Reference	Study Design	Methods	Results
L	Cherry KE, Sampson L, Nezat PF, Cacamo A, Marks LD, Galea S (2015) Long-term psychological outcomes in older adults after disaster: relationships to religiosity and social support. Aging Ment Health. 2015;19(5):430-43 PMID: 25078872	Cross-sectional. Predictors of long-term psychological outcomes in current residents of disaster affected communities (Hurricanes Katrina and Rita, and Gulf oil spill) (n = 63) and fishers (n = 64), former coastal residents (n = 62), and indirectly affected non-coastal resident controls (n = 30).	Participants completed questionnaires on measures of storm exposure and stressors, religiosity, perceived social support, and mental health. Measures of PTSD (PTSD Checklist-Civilian Version), depression (Patient Health Questionnaire-9), anxiety (Generalized Anxiety Disorder (GAD-7)), Religiosity Questionnaire, perceived social support (Interpersonal Support Evaluation List), and structured storm exposure (SSQ).	More frequent participation in non-organizational religious behaviours associated with a heightened risk of PTSD. Low income and being a coastal fisher significant predictors of depression symptoms. Perceived social support had a protective effect for all mental health outcomes, which also held for symptoms of depression and GAD.

Reviewer	Reference	Study Design	Methods	Results
	Shultz M, Walsh L, Garfin DR, Wilson FE, Neria Y (2015) The 2010 Deepwater Horizon oil spill: the trauma signature of an ecological disaster. J Behav Health Serv Res. 2015 Jan;42(1):58-76 PMID: 24658774	Trauma signature (TSIG) methodology used to examine the psychological consequences in relation to exposure to the unique constellation of hazards associated with the spill.	A hazard profile, a matrix of psychological stressors, and a "trauma signature" summary for the affected Gulf Coast population - in terms of exposure to hazard, loss, and change were created. Psychological risk characteristics included: human causation featuring corporate culpability, large **spill** volume, protracted duration, coastal contamination from **petroleum** products, severe ecological damage, disruption of Gulf Coast industries and tourism, extensive media coverage.	Stressors were counterbalanced by the relative absence of other prominent risks for distress and psychopathology; astal residents did not experience significant shore **spill**-related mortality or severe injury, ortages of survival needs, disruption of vital vices (health care, schools, utilities, mmunications, and transportation), loss of mes, population displacement, destruction of built environment, or loss of social supports; ture of the disaster allowed the infrastructure of astal communities to remain intact; aster response was exemplary; ostantial BP financing was made available to derwrite losses, pay for the clean-up efforts, and pport Gulf Cost economic recovery. Gulf Coast populations display remarkable resilience in the face of daunting challenges, the behavioural health impact of the **Deepwater Horizon spill** appears to have been blunted by the absence of major evidence-based risks for psychological distress and disorder, the exemplary response, and the infusion of economic resources.

Reviewer	Reference	Study Design	Methods	Results
	Hansel TC, Howard J. Osofsky HJ, Osofsky JD, Speier A (2015) Longer-Term Mental and Behavioral Health Effects of the Deepwater Horizon (DHW)Gulf Oil Spill. J. Mar. Sci. Eng. 2015, 3, 1260-1271	Survey to improve understanding of the longer-term mental and behavioural health effects of the DWH Gulf Oil Spill. Effects of exposure to Hurricane Katrina were considered.	314 individuals (female 67%, male 33%; 13% in occupations affected by oil spill; 64% with 2009 annual income less than $40,000; 25% applied for financial assistance after spill). First data set collected one year following the spill, second set one year after the second anniversary.	Mental health symptoms of depression, serious mental illness and post-traumatic stress did not statistically decrease; anxiety symptoms statistically equivalent to immediate symptoms. Greatest effect on anxiety related to the extent of disruption to participants' lives, work, family, and social engagement.
	Rung AL, Oral E, Fontham E, Harrington DJ, Trapido EJ, Peters ES (2015) Mental Health Impact of the Deepwater Horizon Oil Spill Among Wives of Clean-up Workers. Epidemiology. 2015 Jul;26(4):e44-6. PMID: 25924110	to determine the impact on 252 female partners of male participants in the National Institute of Environmental Health Sciences Gulf Long-term Follow-up Study.	Telephone survey between Nov 2011 and Jun 2013.	31% prevalence of depression in the sample; 33% reported increases in domestic fights; 31%–32% reported memory loss post-spill; 39%–43% reported an inability to concentrate post-spill.

Reviewer	Reference	Study Design	Methods	Results
	Shenesey JW, Langhinrichsen-Rohling J (2015) Perceived resilience: Examining impacts of the Deepwater Horizon oil spill one year post-spill. Psychol Trauma. 2015 May;7(3):252-8. PMID: 25961118	Cross-sectional. One year follow up to Gill et al., 2012. 812 Alabamian residents of Mobile (*n* = 434) and Baldwin (*n* = 378) counties; women (64%), men (36%); mean age of 50 years; white (92%), African American (5%), Hispanic/ Latino (4%), 1% other (1%); married (70%); some college/vocational school (33%) or a high school diploma (28%). Most had a household income of $50,000 or lower.	Telephone survey between Apr 1 and Apr 28, 2011. Adapted from the original telephone survey with additional questions to measured self-perceptions of resilience and depressive symptoms. PTSD symptoms assessed using Impact of Events Scale. Depressive symptoms assessed using seven questions from the Center for Epidemiological Studies Depression 10-item scale (CES-D-10).	739 participant considered themselves resilient (33% very resilient, 58% moderately resilient). 7.6% considered themselves non-resilient. Resilience groups did not differ by age. Men considered themselves more resilient than women. Lower perceived resilience associated with greater ongoing depressive and PTSD symptoms.

Reviewer	Reference	Study Design	Methods	Results
	Cherry KE, Sampson L, Galea S, Marks LD, Baudoin KH, Nezat PF, Stanko KE (2016) Health-Related Quality of Life in Older Coastal Residents After Multiple Disasters Disaster Med Public Health Prep. 2017 Feb;11(1):90-96 PMID: 27974075	Study to address age differences in health-related quality of life in older disaster survivors exposed to the 2005 Hurricanes Katrina and Rita and the 2010 BP Deepwater Horizon oil spill (219 people; 92 non-coastal and former coastal residents, 63 current coastal residents with catastrophic property damage and storm-related displacement in 2005, 64 commercial fishers and their family members) and the role played by social engagement in influencing these differences.	Social engagement estimated on the basis of disruptions in charitable work and social support after the 2005 hurricanes relative to a typical year before the storms. Criterion measures were participants' responses to the Medical Outcomes Study Short Form-36 (SF-36) which includes composite indexes of physical (PCS) and mental (MCS) health.	Age was inversely associated with SF-36 PCS scores. A reduction in perceived social support after Hurricane Katrina was also inversely associated with SF-36 MCS scores.

Reviewer	Reference	Study Design	Methods	Results
	Lowe SR, Kwok RK, Payne J, Engel LS, Galea S, Sandler DP (2016) Why Does Disaster Recovery Work Influence Mental Health? Pathways through Physical Health and Household Income. Am J Community Psychol. 2016 Dec;58(3-4):354-364. PMID: 27704561	As part of the NIEHS GuLF STUDY, participants reported on clean-up work activities, spill-related physical health symptoms, and household income at baseline (March 2011 to March 2013) (W1) and mental health symptoms at subsequent home visit assessments an average of 14.69 weeks later (SD = 16.79) (W2). 10,141 participants (male 78.2%; white 53.7%, black 35.5%; age 44.04 years (21-90); 21.8% with less than a high school education). 7916 workers, and 2225 non-workers.	Among workers, the average duration of clean-up work was 142.25 days (SD = 139.75), and the average maximum level of oil exposure was 4.50 (SD = 1.08; Range: 2–7). W2 assessment conducted in the participant's home and consisted of collection of biological samples, clinical assessments, and additional interview data collection, including structured mental health indices.	Cleanup work participation associated with higher physical health symptoms, which were associated with higher to post-traumatic stress (PTS), major depression (MD), and generalized anxiety disorder (GAD). At W2, 5.5% of participants met the criterion for probable PTSD, 24.9% for probable GAD, and 16.5% for probable MD. W2 participants reported significantly lower socioeconomic status, more health problems, and were more likely to be racial/ethnic minorities. Longer worker duration and higher work-related oil exposure were associated with higher household income, which was associated with lower MD and GAD symptoms. These findings suggest that physical health symptoms contribute to workers' risk for mental health symptoms, while higher household income, potentially from more extensive work, might mitigate risk. Limitations of study discussed.

Reviewer	Reference	Study Design	Methods	Results
	Osofsky JD, Osofsky HJ, Weems CF, Hansel TC, King LS (2016) Effects of Stress Related to the Gulf Oil Spill on Child and Adolescent Mental Health J Pediatr Psychol. 2016 Jan-Feb;41(1):65-72 PMID: 25306404	Naturalistic study. Prospective design, with 1,577 youth (aged 3–18 years; 56% girls; 56% White, 25% Black, 7% "mixed," 4% Hispanic, 4% Asian, and 4% other; 73% eligible to receive subsidized or free lunch).	PTSD symptoms measured with the Katrina Inspired Disaster Screenings, a modified version of the National Child Traumatic Stress Network Disaster (NCTSN) Assessment and Referral Tool for Children and Adolescents. Evaluated for PTSD symptoms and hurricane exposure between Sep 2009 and Mar 2010 pre-oil spill (Time 1), and again evaluated between Sep and Dec2010, post-oil spill (Time 2), for PTSD symptoms and amount of Gulf oil spill-related stress.	Mean PTSD symptoms scores were 27.94 (10.5) and 27.56 (10.4) for the two time points, and intraclass correlation coefficients (ICC absolute agreement) indicated a fairly high level of stability in PTSD symptoms (Time 1 to 2 ICC=0.61). Stressors related to the **spill** were common and were associated with PTSD symptoms. Interactive effect such that those with high preexisting PTSD symptoms, high previous hurricane exposure, and high **oil spill** stress had the most elevated post-**oil spill** PTSD symptoms.
	Rung AL, Gaston S, Oral E, Robinson WT, Fontham E, Harrington DJ, Trapido E, Peters ES (2016) Depression, Mental Distress, and Domestic Conflict among Louisiana Women Exposed to the Deepwater Horizon Oil Spill in the WaTCH Study Environ Health Perspect. 2016 Sep;124(9):1429-35 PMID: 27164620	Population-based sample of 2,842 women from Women and Their Children's Health Study. Participants asked about depression, mental distress, domestic conflict, and exposure to the oil spill.	Telephone interviews conducted between Jul 2012 and Aug 2014. Depression measured using the 20-item Center for Epidemiological Studies Depression (CES-D) Scale, with an established cutoff score of 16 suggestive of depressive symptoms; mental distress measured using the Kessler-6 (K6) instrument with scores greater than or equal to13 indicating probable serious mental distress and scores between 8 and 12 indicating moderate mental distress.	28% of the sample reported symptoms of depression, 13% reported severe mental distress, 16% reported an increase in the number of fights with their partners, 11% reported an increase in the intensity of partner fights. Both economic and physical exposure significantly associated with depressive symptoms and domestic conflict, whereas only physical exposure was related to mental distress.

Annex G: Guidance on onsite response to pipeline incidents, derailments and marine incidents

Response to a pipeline incident

The Emergency Response Guidebook (ERG2016) [ERG, 2016] provides general instructions for responders to pipeline incidents. (Indications of pipeline ruptures are given on page 22.)

Safety of both the responder and the community is the top priority.

The responder should approach a pipeline incident from upwind, uphill, and upstream while using air monitoring equipment to detect for the presence of explosive and/or toxic levels of hazardous materials:

- always wear proper personal protective equipment;
- never attempt to operate pipeline valves;
- never attempt to extinguish a flame before shutting off supply, as this can cause formation of explosive mixtures; and
- do not enter a vapour cloud in an attempt to identify the product(s) involved.

ERG 2016 tells responders to (see page 24):

- identify the operator and, if possible, the product;
- notify the pipeline operator;
- establish a command post;
- secure the site; and
- develop a plan to evacuate or shelter-in-place.

ERG 2016 discusses factors to be considered in determining protective action distances for crude oil release from ruptured pipelines (see below).

Response to a derailment

The advice given in the case of a derailment would be similar to that given for a pipeline rupture except that the rail company would be notified. Information specific to derailments involving Bakken crude oil is given in a report by the NWAC [NWAC, 2015].

Response to a marine incident

Canadian response to marine oil spills is detailed in the Canadian National Oil Spill Preparedness and Response Regime [TC, 2012]. The Canadian Coast Guard (CCG) oversees the response to ship-source oil spills in Canadian waters. The onus for responding to pollution incidents is placed on the polluter who hires a response organization to do the clean-up. The four certified response organizations, based on geographical areas, are described in reference [TC, 2016].

The CCG monitors the polluter's efforts and steps-in to manage the response only if a polluter is unknown, unwilling, or unable to respond to an incident. The CCG can seek compensation for costs incurred when managing or monitoring the response to an incident.

Transport Canada guidelines for reporting incidents involving marine pollutants are given in reference TC, 2016 and regional contact numbers for reporting a marine pollution incident in reference CCG, 2015.

Initial isolation and protective action distances

The determination of protective action distances is best left to the incident response team (HAZMAT coordination/incident commander/industry expert).

The **Initial Isolation Zone** defines an area SURROUNDING the incident in which persons may be exposed to dangerous (upwind) and life threatening (downwind) concentrations of material.

The **Protective Action Zone** defines an area DOWNWIND from the incident in which persons may become incapacitated and unable to take protective action and/or incur serious or irreversible health effects (see Figure G–1).

The ERG 2016 provides general guidance on initial isolation zones and protective action zones.

Crude oil (UN 1267) is classified as a flammable liquid (Water-Immiscible). Guide 128 suggests that for large spills (greater than 208 litres) an initial downwind evacuation for at least 300 metres be considered. If a tank, rail car, or tank truck is involved in a **fire**, an isolation distance of 800 metres in all directions should be put in force and an initial evacuation for 800 metres in all directions considered.

Sour crude oil (UN 3494) is classified as a flammable liquid (Toxic). Guide 131 suggests that for a spill, the initial isolation distance and protective action distance given in ERG 2016 should be used (see Table G–1). It further states that if a tank, rail car, or tank truck is involved in a **fire**, an isolation distance of 800 metres in all directions be put in force and an initial evacuation for 800 metres in all directions be considered.

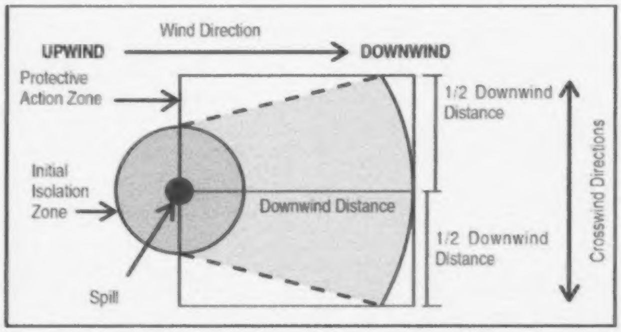

Figure G–1: Initial isolation zone and protective action distance

Table G–1: Initial Isolation Distances and Protective Action Distances for sour crude oil (UN 3494) spills [ERG2016]

SMALL SPILLS** (From a small package or small leak from a large package*)			LARGE SPILLS** (From a large package or from many small packages)		
First ISOLATE in all directions (metres)	Then PROTECT persons downwind during		First ISOLATE in all directions (metres)	Then PROTECT persons downwind during	
	Day (km)	Night (km)		Day (km)	Night (km)
30	0.1	0.2	60	0.5	0.7

* package = packaging plus contents

** Spills that involve releases of approximately 208 litres for liquids (55 US gallons) and 300 kg for solids (660 lbs) or less are considered Small Spills, while spills that involve greater quantities are considered Large Spills

The ERG 2016 notes that the following factors should be considered in determining protective action distances for crude oil release from ruptured pipelines (ERG, 2016):

1. type of crude oil (e.g., sour vs. sweet);
2. extent and type of spill (visual observations, e.g., geyser from ruptured pipe, slowly bubbling out of ground);
3. pressure and diameter of pipe;
4. timing of valve closure by utility (quickly for automated valves and longer for manually operated valves);
5. dissipation time of material in pipe once valves closed;
6. ability to conduct atmospheric monitoring and/or air sampling;
7. weather (wind direction, etc.)
8. local variables such as topography, population density, demographics, and fire suppression methods available;
9. nearby building construction material and density; and
10. natural and man-made barriers (highway).

In addition to factors 1, 6, 7, 8, 9, and 10, the following factors would be considered in the case of a derailment:

- has a fire or explosion occurred or does it appear to be imminent; and
- the number of tank cars derailed and their condition (e.g., do the cars appear to be leaking)

References

Canadian Coast Guard (CCG, 2015) Report Marine Pollution [http://www.ccg-gcc.gc.ca/eng/CCG/ER_Reporting_Incident]

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Annex H: Personal protective equipment (PPE)

Responders should avoid all contact with crude oil through the use of personal protective equipment, if possible.

The ERG 2016 recommends that those responding to an incident involving chemicals included in Guides 128 (crude oil UN 1267) or 131 (sour crude oil UN 3494) wear positive pressure self-contained breathing apparatus (SCBA) [ERG, 2016].

Wearing SCBA is a very prudent procedure that will protect the responder from inhalation hazards posed by any hazardous chemical(s) present in the initial release or produced because of a fire and will ensure that the responder has adequate oxygen. It also eliminates the need to identify all the hazardous chemicals present (e.g., hydrogen sulfide in the case of sour crude oil, VOCs) and their concentrations and to measure the oxygen concentration.

The use of SCBA requires training and is, consequently, only available to first responders (e.g., HazMat, Fire, and Police). Clean-up workers and others who have a legitimate need to access the incident site must be provided with suitable alternative respiratory protection. The U.S. Occupational Safety and Health Administration (OSHA) provides respiratory protection standards and requirements in reference OSHA, 2015.

Responders should wear oil-resistant gloves, protective clothing, and slip-resistant footwear, appropriate for the particular release and task [Wireless Information System for Emergency Responders (WISER), 2014].

Due to the weight and impermeability of PPE, clean-up workers must be monitored for signs of heat stress under warm weather conditions. The primary health impact on DWH clean-up workers was heat exhaustion [King & Gibbins, 2011].

The U.S. National Institute for Occupational Health (NIOSH) and OSHA have produced detailed information on personal protective equipment, including respirators, required for the DHW light oil spill clean-up operations [NIOSH, 2010a; NIEHS, 2010].

The U.S. National Institute of Environmental Health Sciences (NiEHS) provides courses and training tools for oil spill response workers [NIEHS, 2016].

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Annex I: Derailments involving crude oil in Canada and the United States since the Lac-Mégantic derailment

Date	Location	Description	Consequences
2016 Jun 3	**Mosier, OR**	Union Pacific train with 96 cars loaded with Bakken crude	• 16 cars derailed • four cars caught fire; approximately 47,000 gallons of crude oil escaped from these cars • residents in an area about 0.35 mile around the incident evacuated • water supply affected; 13,000 gallons flowed into wastewater treatment plant • 2,960 tons of petroleum contaminated soil removed • water and air at site monitored [ODEQ, 2017]
2015 Jul 16	**Culbertson, MT**	BNSF train with two locomotives, two buffer cars, 106 cars loaded with Bakken crude	• 22 cars derailed • four cars leaked an estimated 35,000 gallons • no explosions or fire • evacuation of about a dozen homes and a camp for oil field workers • closure of federal Highway 2 [Brown and Volz, 2015]
2015 May 6	**Heimdal, ND**	BNSF crude oil unit train (107 tank cars, three locomotives, two buffer cars) derailed oil stripped of volatiles (propane, butane and other volatile gases) prior shipment (vp 10.8 psi) unjacketed DOT-111A100W1 cars meeting (CPC)-1232 standard speed 45 mph cause – broken wheel	• Six cars derailed, five breached, about 96,400 gallons of crude oil released, fire resulted • no injuries reported, about 30 people evacuated from town and farms • oil contained in slough being recovered • damage estimated at $5 million US • [Brown and Nicholson, 2015; Mouawad, 2015; NTSB, 2017c]

Date	Location	Description	Consequences
2015 Mar 7	**Gogama, ON**	Canadian National Railway (CNR) crude oil unit train U70451-02 with two head-end locomotives, 94 Class 111 tank cars loaded with Petroleum Crude Oil (UN 1267) train 5,733 ft long; weighed 13,497 tons speed 43 mph cause: inadequate repair of damaged rail	• 39 cars derailed; 33 cars breached, some released product entered the river • a pool fire 300 yards in diameter resulted, all fires extinguished by 10 Mar 2015 • of the more than 4 million litres of petroleum in the breached cars, 1.6 million burned to atmosphere, 1 million lost to surface or water, 1.4 million recovered, • rail bridge and 1000 feet of track destroyed • no injuries reported, no evacuation required (isolated area) • Mattagami First Nation is suing CN Rail for $30 million for alleged environmental and cultural damage claiming that the 7 Mar and 14 Feb spills created health risks for the population and crippled community members' ability to observe their Indigenous traditions including fishing, hunting and gathering [TSB, 2015; TSB, 2017b; McQuigge, 2017]
2015 Mar 5	**Galena, Il**	BNSF train with105 cars, 103 containing 630,000 gallons of Bakken crude speed 23 mph DOT-111 cars meeting (CPC)-1232 standard	• 21 cars derailed, seven cars ruptured; five of the ruptured cars caught fire; fires extinguished by 8 Mar • more than 260,000 gallons of crude oil and oil-water mix recovered; approximately 217,000 gallons of contact water treated; more than 3,500 tons of contaminated soil excavated. • homes within one mile of the derailment site evacuated [EPA, 2015a]
2015 Feb16	**Mount Carbon, WV**	CSX train with two locomotives, 107 fully loaded tank cars carrying Bakken crude oil (approx. 3.1 million gallons) and two covered hopper buffer cars speed 33 mph cause: broken rail unjacketed DOT-111 cars meeting (CPC)-1232 standard	• 27 loaded cars derailed; two cars punctured, released oil which ignited and caught fire; pool fire resulted in thermal tears in 13 additional cars; 24 cars suffered significant damage • estimated 362,300 gallons released - much lost to atmospheric burn, pool fires and ground absorption; fire burned for more than 30 hours • some oil entered Kanawha River • one person injured (smoke inhalation); one home/one garage destroyed; • five-day evacuation within a half-mile of the incident site, affecting approximately 1,100 residents • total costs more than $23 million [FRA, 2015]

Date	Location	Description	Consequences
2015 **Feb 14**	**Gogama, ON**	CN crude oil unit train U70451-10 with two head-end locomotives, 100 Class 111 tank cars, 68 loaded with Petroleum Crude Oil (UN 1267) and 32 loaded with Petroleum Distillates (UN 1268) train 6089 ft long; weight 14355 tons speed 38 mph 29 cars derailed, 25 damaged cause: insulated rail joint failure	• no injuries reported, no evacuation required (isolated area) • 19 tank cars released petroleum crude oil; during derailment, 14 tank cars were breached and released product that pooled on both sides of the track; pooled product ignited; the ensuing fire engulfed five additional tank cars, which sustained thermal tears • approx. 1.7 million litres of product released to either atmosphere or surface; fire burned for five days • all cars constructed within last three years to industry's CPC-1232 standard • about 900 feet of mainline track destroyed [TSB, 2017a]
2014 **Apr 30**	**Lynchburg, VA**	CSX unit train K08227, with two locomotives, one buffer car and 104 cars carrying Bakken crude oil speed 24 mph possible cause – broken rail	• 17 tank cars derailed in the City of Lynchburg; three partially submerged in James River • one car breached releasing 29,868 gallons of crude oil into the river, some caught fire • no injuries reported; 350 residences and 20 businesses evacuated • estimated damages $1.2M US plus cost of environmental remediation [NTSB, 2016]
2014 **Feb 12**	**Vandergrift, PA**	120 car Norfolk Southern train carrying heavy Canadian crude oil; 21cars derailed	• 19 of derailed cars contained oil; two contained LPG; four oil cars ruptured; 3,000-4,000 gallons spilled [Gibbons, 2014]
2014 **Jan 31**	**New Augusta, MS**	85 car CN train, carrying fuel oil 19 cars derailed	• five cars leaked – three oil (3,000-4,000 gallons spilled), one methanol, one fertilizer • no injuries; mandatory evacuation within a 1,000 ft radius – 50 people evacuated • highway closed • [MSEMA, 2014]
2014 **Jan 7**	**Plaster Rock, NB**	122 car CN train; 19 cars and locomotive derailed; nine cars contained crude oil and liquefied petroleum gas (LPG)	• two older DOT-111 tanks cars punctured releasing oil; fire resulted • two km radius around fire evacuated – 50 homes and approx. 150 people • 50 wells tested for pollution [TSB, 2014]
2013 **Dec 30**	**Casselton, ND**	BNSF 104-car oil unit train with three locomotives crashed into a grain train; two head-end locomotives, buffer car, 20 oil cars derailed speed 42 mph probable cause: broken axle	• 18 cars breached; 476,000 gallons of crude oil released, much lost to atmospheric burn, pool fires and ground absorption • about 1400 people evacuated • approximately 9,000 cubic yards of soil and debris removed from impacted area • cost $13.5million US [NTSB, 2017a; NTSB, 2017b]

Date	Location	Description	Consequences
2013 Nov 7	**Aliceville, AL**	Alabama & Gulf Coast RR (AGR) Train 501-07 - three locomotives, two buffer cars, 88 DOT-111 tank cars carrying Bakken crude	• 26 cars derailed; 23 breached; three exploded; fire visible for 10 miles • cars estimated to contain 748,703 gallons; approx. 208,952 gallons recovered from tank cars once the fire was extinguished; 11,932 gallons skimmed from surface water • clean up costs estimated at $3.9 million US [EPA, 2015b]
2013 Oct 19	**Gainford, AB (about 80 kms west of Edmonton)**	Canadian National freight train M30151-18, derailed 13 tanker cars – four laden with petroleum crude oil and nine carrying liquefied petroleum	• two LPG cars breached and caught fire; third LPG car released product • no injuries;106 homes evacuated • highway closed; 600 ft of track destroyed [TSB, 2013]

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Annex J1: Recent pipeline accidents involving crude oil in Canada and the United States

Date	Location	Company	Description	Consequences
2016 Jul 21	**North Saskatchewan River**	Husky	pipeline burst, between 200,000 and 250,000 litres of crude oil and other material leaked into the North Saskatchewan River shifting ground blamed for burst	• cities of North Battleford, Prince Albert, Melfort forced to shut off their water intakes from the river and find other water sources for almost two months • about 210,000 litres recovered • cost: $107 million Cdn responding to the spill • Saskatchewan government raised penalty provisions to a maximum of $500,000 per day • [Graham, 2016, Saskatchewan Government (SG), 2016; Healing, 2017]
2015 Jul 16	**south of Fort McMurray, AB**	Nexen Energy	5,000,000 litres of a bitumen-water-sand emulsion leaked from a pipeline	• spill covered an area of about 16,000 square metres, release mainly isolated to the pipeline • [CBC, 2015; Alberta Energy Regulator, 2016]
2015 May 19	**Santa Barbara County, CA (Refugio Incident)**	Plains Pipeline, LP	901 pipeline ruptured approximately 2,934 barrels of heavy crude oil released	• estimated 500 barrels of crude oil entered the Pacific Ocean; substantial damage to natural habitats and wildlife; 204 birds and 106 marine mammals died • company indicted on 46 criminal counts, including four felony charges of knowingly discharging a pollutant into state waters • [NOAA, 2015; Smith, 2015; DOT, 2016a]
2015 Jan 17	**five miles upstream of Glendive, MT**	Bridger Pipeline Popular System	12 in pipeline burst; at 28,434 gallons of Bakken crude oil gushing into the Yellowstone River	• Order – do not drink water; EPA – benzene levels above safety • $1 million US civil penalty • [DOT, 2016b; Stuart, 2016]
2014 Nov 30	**Red Earth Creek, AB**	Canadian Natural Resources	pipeline experienced mechanical failure approx. 60,000 litres of crude oil spilled	• wildlife was not affected • low amounts of hydrogen sulphide gas detected • [CBC News, 2014b]
2014 Apr 3	**near Slave Lake, AB**	Canadian Natural Resources	above ground pipe failure, spilled 70,000 litres of oil and processed water	• [CBC News, 2014a]
2013 Oct 10	**Tioga, North Dakota**	Tesoro Logistics	pipeline leaked 20,600 barrels of Bakken crude oil into wheat field	• no injuries; no water pollution; oil isolated within 7.3 acre area • clean up costs estimated more than $11million US • [North Dakota Dept. of Health, 2016; Dalrymple, 2014]

Date	Location	Company	Description	Consequences
2013 **Mar 29**	**Mayflower, AR**	Exxon Mobil	Pegasus pipeline carrying Canadian Wabasca heavy crude oil ruptured	• 3,190 barrels of oil released • oil spilled into the surrounding area, flowed into Lake Conway; wetland vegetation, waterfowl and various other wildlife were impacted • 21 homes evacuated • Exxon required to: provide additional training to its oil spill first responders and establish caches of spill response equipment and supplies at three strategically chosen sites along the pipeline • $3,190,000 US federal civil penalty paid to the Oil Spill Liability Trust Fund [EPA, 2015]
2012 **Jul 27**	**Grand Marsh, WI**	Enbridge	pipeline leaked more than 1,000 barrels of crude oil into field	• one family evacuated • [O'Brien, 2012]
2012 **Jun 7**	**Red Deer River, AB**	Plains Midstream Canada (PMC)	pipeline leaked 461,000 litres of sour crude oil into river near Sundre	• Alberta Energy Regulator concluded that PMC: 1. didn't inspect its pipeline often enough; 2. didn't pay enough attention to government warnings; 3. failed to enact adequate mitigation measures once the leak occurred; 4. communicated poorly with hundreds of people affected by the spill • PMC charged with two counts of violating environmental laws in June 2014 • PMC fined $1.3 million after pleading guilty to the charges for this spill 2012 and 2011 Rainbow Lake spill [CBC News, 2014c]
2012 **Jun 19**	**Elk Point** northeast of Edmonton, AB	Enbridge	pipeline flange gasket failed at pumping station about 230,000 litres of crude oil spilled	• spill was almost completely contained on the site • no impact on wildlife or water • [CBC, 2012]
2012 **Mar 2**	**New Lennox Township, IL**	Enbridge	drag racing car crashed into pipeline, rupturing line, causing explosion and fire	• two men killed; three seriously injured • 20,000 gallons spilled • pipeline shut down for more than six days • [CBS, 2012]
2012 **Jan 24**	**Sumas Terminal, Abbotsford, B.C.**	Kinder Morgan Energy Partners	90 m³ of light crude spilled from storage tank on Sumas Mountain into containment area	• residential area and school affected by fumes • [TransMountain Pipeline, 2012]

Date	Location	Company	Description	Consequences
2011 Jul 1	**Yellowstone County, MT,** approx.20 miles upstream of Billings, MT	ExxonMobil	1,500 barrels of crude oil released into the Yellowstone River	• no injuries; 140 people evacuated • river and its floodplain affected for approximately 85 miles downstream • little oil recovered • $135 million US estimated combined cost; fine of $1.6 million US [MDEQ, 2016]
2011 Apr	**Rainbow Lake, 100 km north-**east of Peace River, AB	Plains Midstream Canada	28,000 barrels leaked	• contaminated more than three hectares of beaver ponds and muskeg • residents of Little Buffalo, 30 km from the spill site northeast of Peace River, claimed fumes from the leaking crude made them sick with nausea, burning eyes and headaches • company charged with three counts of violating environmental protection laws • [CBC, 2011; CBC, 2013c]
2010 Sep 9	**Romeoville, IL**	Enbridge Energy	pipeline liked beneath the street pavement in an industrial park	• 6,430 barrels of Saskatchewan heavy crude oil flowed into a storm water drainage ditch, then to a storm water management pond • 50 persons evacuated from 11 nearby businesses • 23 area businesses closed for one to nine days • damages, including the cost of the environmental remediation, totalled about $46.6 million US [NTSB, 2013]
2010 Jul 25	**Marshall, MI**	Enbridge Energy	crude oil pipeline ruptures spilling about 843,444 gallons of crude oil into the Kalamazoo River	• 30-50 households asked to evacuate • 320 people reported symptoms consistent with crude oil exposure • nearly 4,000 animals sickened • 35 miles of wetlands and waterways soiled • clean-up costs $1.21 billion U.S • (see Case study 2) [NTSB, 2012]
2009 May 7	**Burnaby, B.C.**	Kinder Morgan Energy partners	200,000 litres of crude oil spilled from a storage tank	• captured in a lined containment bay surrounding the tank • spill affected soil and groundwater in the vicinity of the tank bay, as well as sediment, water and wildlife in the tertiary retention area [Wintonyk, 2009]

Date	Location	Company	Description	Consequences
2007 **Jul 24**	**Burnaby, B.C.**	Kinder Morgan Energy partners	excavator ruptured 4-inch pipeline, resulting in a 12-15 m geyser of oil spraying into the air & covering surrounding area with oil over approximately a 25 min period	• no explosion, fires or injuries • emergency workers, two firefighters and two civilians sprayed with oil • 250 people evacuated • 50 homes affected – 11 seriously impacted • 234,000 litres of oil released into residential neighbourhoods and ocean; 210,000 litres recovered • highway closed for several days • clean up costs greater than $15 million; fines of $1,000 for each of three companies involved [BCENV, 2016; TSB, 2009; Raptis, 2011]

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Annex J2: Major international crude oil spills involving pipeline/storage tank/onshore wells

Date	Location	Company	Description	Consequences
2013 **21 Nov**	**Qingdao, China**	Sinopec	• pipeline ruptured; leaked for about 15 min onto a street and into the sea before being shut off; hours later, as workers cleaned up the spill, the oil caught fire and exploded in two locations • direct cause of the explosion: vapours from oil leaking from an underground pipeline ignited by sparks from a hydraulic hammer	• 62 dead; 136 injured • 18,000 residents evacuated • oil spread across 3,000 square metres in Jiaozhou Bay and Yellow Sea • losses of more than $122.7 million • [AFP, 2014; Reuters, 2013, Zhu, 2015]
2010 **20 Dec**	**San Martin Texmelucan**	Petroleos Mexicanos (Pemex)	• blasts at pumping station caused by illegal taping into high-pressure pipe	• at least 28 people killed; at least 52 people injured; 5,000 people evacuated; 32 houses destroyed; 83 houses damaged [Seattle Times, 2010]
2010 **17 Jul**	**port of Dalian, China**	China National petroleum, Corp	• explosion of two petroleum pipelines and subsequent fire in the port • cause: improper injections of strongly oxidizing desulfurizer into the oil pipeline	• fatalities • 1,500 thousand tons of oil released into the Yellow Sea, spread over 430 km² of sea and coast line; economic and ecological damage • [CBSNews, 2010; Watts, 2010]
2008 **16 Mar**	**Donges-Refinery, Loire-Atlantique, France**	Total Raffinage Marketing	• pipe leak caused a spill of an estimated 400 tonnes of heavy fuel oil (IFO 380) during the loading of a vessel	• temporary ban on fishing; shoreline pasturage damaged • fine: €300,000 • [Cedre, 2014]
2008 **16 May**	**Ijegun, Nigeria**		• bulldozer struck and ignited pipeline	• more than 100 killed [Connors, 2008]
2007 **Jan**	**Ambès (Gironde, France)**	Vermilion Emeraude Rep; operated by the Société Pétrolière du Bec d'Ambès (SPBA)	• crude oil storage tank at oil storage depot gave way; 13,500 m³ of Aquitaine crude oil, released, creating a wave effect causing some 2,000 m³ of oil to spill over the top of the retention tank; nearly 2 km of marshland trenches and channels contaminated; water table reached; 50 m³ reached Garonne River	• over 10 km of river bank polluted • €30,000 fine for SPBA; a €5,000 fine for the company's former Managing Director [Cedre, 2014]

Date	Location	Company	Description	Consequences
2006 **26 Dec**	**Abule Egba, Nigeria**		• thieves rupture pipeline	• at least 260 killed; 60 injured; number of houses, a mosque and a church destroyed [BBC, 2006a]
2006 **13-15 Jul**	**Lebanon, 30 km south of Beirut**	Jieh electric power	• bombings in southern Lebanon hit the Jieh electric power plant; part of the heavy fuel oil burned.	• 10,000 to 15,000 tonnes of unburned fuel oil IFO 150 (Intermediate Fuel Oil with a viscosity of 150 cSt at 50°C) spilled onto the shoreline; pollution impacted almost half of the 200 km of Lebanese coastline [Cedre, 2006]
2006 **12 May**	**Atlas Creek Island, Nigeria**		• vandals drilled holes into pipeline, explosion resulted	• at least 150 killed • police investigation and increased protection for other pipelines ordered [BBC News, 2006b]
2004 **14 Sep**	**near the city of Beiji, Iraq**		• saboteurs attacked a location where several pipelines meet to cross the Tigris river	• burning crude oil escaping from the fractured pipelines ran downhill into the river; fire took three days to control [Cedre, 2014]
2003 **22 Jun**	**Abia, Nigeria**		• siphoning fuel from a ruptured pipeline which was ignited by a spark	• at least 105 killed [BBC News, 2003]
2000 **Jul**	**Warri, Nigeria**			• at least 300 killed [BBC News, 2006, allafrica, 2000]
1998 **Oct**	**Jesse, Nigeria**	Nigerian Petroleum Corp	• scavengers intentionally ruptured the pipeline with their tools and ignited the blaze	• 1,082 killed; fire burned for a week • [Reuters, 2008; Okpo, 2012]
1992 **2 Mar**	**Fergana Valley, Uzbekistan (Mingbulak oil spill)**		• blowout at well no. 5; oil released and burned for two months; releasing 150,000 B/D, the flow of oil stopped of its own volition	• total of 285,000 tons of oil released; 320,000 m^3 collected behind emergency dykes • [Beckworth, 2012]
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Annex K: List of Major Crude Oil Spills – Marine Spills Involving Ships

Incident	Date	Location	Description	Consequences
SANCHI	**2018** Jan 6	East China Sea	tanker collide with freighter CF Crystal	almost one million barrels of condensate released; caught fire; tanker sank eight days later 32 crew and passengers presumed dead [Reuters, 2018; Erickson, 2018]
SOUTHERN STAR 7	**2014** Dec 9	south of the Port of Mongl, Bangladesh	small tanker *Southern Star .7* collide with another vessel and sank	350 tonnes of furnace oil (similar to IFO 380) released into the Shela River; spill spreading over 80 km of shoreline on UNESCO World Heritage Site; high impact on population; no major widespread impact on wildlife; impact on the mangrove relatively limited [Cedre, 2016; NOAA, 2014]
MV MISS SUSAN/ MV SUMMER WIND	**2014** Mar 22	Houston Ship Channel, Lower Galveston Bay, Texas	bulk carrier Summer Wind collided with the Miss Susan tow (a 70-foot-long towing vessel and two 300-foot-long tank barges loaded with fuel oil); collision breached the hull of the forward tank barge in the Miss Susan tow; about 168,000 gallons of fuel oil (RMG 380) spilled into the waterway	two crew injured due to fumes; about 13 miles of shoreline heavily oiled; about 40 miles lightly to moderately oiled; environmentally sensitive areas involved; about 18 % of the spill recovered as liquid oil; about 25% evaporated or dispersed in the environment; remaining 57% collected from shorelines as solid waste total estimated damage to vessels of nearly $1,378,000 (excluding oil response and recovery efforts) probable cause of the collision: Miss Susan captain's attempt to cross the Houston Ship Channel ahead of the Summer Wind, thereby impeding the passage of the bulk carrier, which could transit only within the confines of the channel [NTSB, 2015]
LUNO	**2014** Feb 5	Cavaliers breakwater France	cargo vessel hit the Cavaliers breakwater; stern section broke off in two parts which sank against the Cavaliers breakwater	20 tonnes of fuel contained in the rear bunkers released into the marine environment; around 60 tonnes of fuel recovered from bow [Cedre, 2016]
CMA CGM FLORIDA	**2013** Mar 17-18	mouth of the Yangtze River	container ship CMA CGM Florida collided with the bulk carrier Chou Shan; container ship sustained several breaches, in particular in its bunker tank	650 tonnes of fuel oil spilled; the oil slick covered an area two nautical miles wide by two hundred nautical miles long [Cedre, 2014]
MV TYCOON	**2012** Jan 8	Port of Christmas Island	vessel broke its moorings while in dock in the Port of Christmas Island; foundered on the cliffs of Flying Fish Cove; broke in two on10th January and then finally in three in February	cargo: 102 tonnes of intermediate fuel oil, 11,000 litres of lubricant oil, 32 tonnes of diesel oil, 260 tonnes of phosphate; oil slick did not have a significant impact on the ecosystem [Cedre, 2012]

Incident	Date	Location	Description	Consequences
TK BREMEN	**2011** Dec 16	beach of Kerminihy, Erdeven, France	general cargo ship dragged anchor while in ballast under stormy conditions; sought shelter outside the port of Lorient; vessel subsequently ran aground on the beach	an estimated 70 tonnes of Intermediate Fuel Oil (IFO) 180 spilled compensation fund limited to 2.1 million € [ITOPF, 2016; Cedre, 2014]
RENA	**2011** Oct 11	Astrolabe Reef, 12 nm offshore from Tauranga in the Bay of Plenty, New Zealand	fully cellular containership ran aground carrying 1,368 containers, 11 of which contained dangerous goods; approximately 1,700 tonnes of IFO 380 bunker fuel and 61 tonnes diesel oil onboard	200-300 tonnes of fuel oil released; 1,300 tonnes pumped from vessel; extensive, and in places heavy, oiling of the sandy mainland shoreline, inner Tauranga Harbour, estuaries and rocky offshore islands; more than 1,000 dead oiled birds and 250 live oiled birds, collected; pre-emptive captures of NZ fur seals and the endangered NZ dotterel; 60 km of coastline polluted; owner fined NZ$300,000 (approx. €190,000) for release of hazardous substances and an additional NZ$10,000 (approx. €6,400) for every day the pollution continued [ITOPF, 2016; Cedre, 2011; TAIC, 2014]
GOLDEN TRADER	**2011** Sep 10	twenty nautical miles off the western coast of mainland Denmark	bulk carrier GOLDEN collided with the fishing vessel VIDAR; approximately 205 tonnes of intermediate Fuel Oil (IFO 180) spilled	initial recovery of recovery to 30-60 tonnes of an oil and water mixture; approximately 15 km of Swedish coastline oiled to a significant degree; later 550 tonnes of emulsified oil (greater than70% average water content) and around 15 tonnes of oily kelp and debris collected [ITOPF, 2016]
OLIVA	**2011** Mar 11	Nightingale Island, Tristan da Cunha	ran aground on Nightingale Island; broke up, stern sank	about 1,400 tonnes of Intermediate Fuel Oil (IFO 320) and a proportion of the 70 tonnes of Marine Diesel onboard spilled; oil slicks stretching around eight miles offshore and all around the island; penguins oiled; economically important lobster (Jasus tristani) fishery impacted Cedre, 2012; ITOPF, 2016]
CONTAINER SHIP GODAFOSS	**2011** Feb 17	near the city of Fredrikstad, Norway	container ship grounded; $112m^3$ of oil spilled	$55m^3$ of oil recovered;130 sites lightly oiled along the east coast of Norway; difficulties of recovery and clean up under Arctic conditions [Cedre,2011]
BUNGA KELANA 3	**2010** May 5	Singapore Strait	tanker BUNGA KELANA 3 collided with bulk carrier WAILY	approximately 2,500 tonnes of Bintulu Crude oil released; oil stranded along several km of the southern and eastern shorelines of Singapore and the islands within the East Johor Channel; impacted approximately 35 km of shoreline of the Johor Bahru and Kota Tinggi, Malysia [ITOPF, 2016]

Incident	Date	Location	Description	Consequences
EAGLE OTOME	**2010** Jan 10	Sabine Neches waterway in Port Arthur, Texas	oil tanker EAGLE OTOME collided with two barges and their towing vessel DIXIE VENGENCE; collision resulted in a hole near the No. 1 starboard cargo tank of EAGLE OTOME; 1,800 tonnes of light crude oil (Olmeca Crude-Sour) spilled	majority of the spilled oil contained within a 12 km length of the waterway [ITOPF, 2016; NOAA, 2010; Cedre, 2010]
GÜLSER ANA	**2009** 25-26 Aug	off Faux Cap, Madagascar	ore carrier carrying 39,250 tonnes of phosphorite (phosphate rock), 570 tonnes of heavy fuel oil, 70 tonnes of marine diesel and eight tonnes of lubricating oil grounded; impact of the accident caused a crack in the side of the vessel	part of fuel and cargo released into sea; 50 km of beaches oiled; fishing in the area banned; area's fishermen received transitory compensation from the vessel's insurer [Cedre, 2010]
PACIFIC ADVENTURE	**2009** Mar 11	off Queensland Australia	cargo vessel carrying 620 tonnes of ammonium nitrate; estimated 270 tonnes of oil caught in a cyclone; fuel tank and bunker damaged.	slick 5.5 km long by 500 m wide; 60 km of shoreline affected; 3,000 tonnes of contaminated sand removed from Moreton Island; 65% of oiled beaches rehabilitated; restoration costs $2 million AUS; compensation $25 million AUS [Cedre, 2011]
ADMIRAL KUZNETSOV	**2009** Feb 14	80 km south-west of Cork (Ireland)	errors in a refuelling operation on the Russian aircraft carrier *Admiral Kuznetsov*; 300-500 tonnes spilled; oil slick covered a surface area of 22.5 m²	no damage to coast line [Cedre, 2010]
USHUAIA	**2008** Dec 4	Bahia Guillermina, west coast of the Antarctic Peninsula	ice strengthened cruise vessel carrying total of 440 tonnes of marine gas oil ran aground	three fuel tanks breached, in addition to the sludge and slop tanks; no shorelines threatened or impacted by the oil [ITOPF, 2016]
HEBI SPIRIT	**2007** Dec 7	Taean, South Korea	barge broke free from its tow puncturing three port-side cargo tanks of anchored Hebi Spirit	approx.10,900 tonnes of Iranian Heavy, Upper Zakum and Kuwait Export crude oils released to the sea; impact of the spill extended across three provinces and several hundred km of coastline on the mainland and on numerous islands, along the western coast of South Korea [ITOPF, 2016; Cedre, 2008; NOAA, 2007]
	2007 Nov 11	Kerch Strait	severe storm damaged ten vessels	estimated 1,300 tonnes of heavy fuel oil, 5.5 tonnes of light fuel oil, 25 tonnes of marine diesel, 2.3 tonnes of lubricants spilled; several dozen km of coastline oiled, in Russia and Ukraine; around 200 tonnes of heavy fuel oil recovered; approx. 70,000 tonnes of oiled waste (sand, oil, debris and vegetation) removed to be disposed of in Russia and 6,500 in Ukraine; 30,000 birds killed; cost of environmental damages could be up to €170 million [Cedre, 2014]

Incident	Date	Location	Description	Consequences
COSCO BUSAN	**2007** Nov 7	San Francisco Bay Bridge in California	container ship collided with one of the towers of San Francisco Bay Bridge in California; a 100-foot gash in the hull of the vessel	50,000 gallons of heavy fuel oil (IFO 380) leaked out into San Francisco Bay [Cedre, 2007; USCG, 2008]
SOLAR 1	**2006** Aug 11	Guimaras Straits, some 10 nautical miles south of Guimaras Island, Philippines	tanker, chartered by Petron Corporation, carrying approximately 2,000 tonnes of intermediate fuel oil, encountered problems in rough seas and sank	800 tonnes spilled; about 125 km of shoreline contaminated to varying degrees including approx.500 hectares of mangroves; families evacuated to protect them from the toxic vapours; natural clean up eventually chosen as the solution; a number of fishpond operators, seaweed farmers and tourist businesses suffered losses [ITOPF, 2016; Cedre, 2007]
BRIGHT ARTEMIS	**2006** Aug 4	Persian Gulf	tanker, transporting 250,000 tonnes of oil responder to a distress signal from the cargo ship Amar; cargo ship thrown by a strong gust and hit the oil tanker; tanker torn open over an area of 5 m²	4,500 tonnes of oil released at sea; release far from land; no action taken; marine environment and evaporation left to eliminate left spill. [Cedre, 2007]
HAPPY BRIDE	**2006** Jan4	oil terminal in Donges	the LPG tanker the Sigmagas collided with the LPG tanker the Happy Bride at oil terminal; tank containing 60 m³ of heavy bunker fuel oil on Happy Bride punctured	60 tonnes of oil spilled; beaches contaminated [Cedre, 2011]
MSC AL AMINE	**2005** Feb 15	Gulf of Tunis near the Korbous	container ship MSC Al Amine grounded	100 – 150 tonnes spilled [Cedre, 2011]
SELENDANG AYU	**2004** Dec 8	off Skan Bay, Unalaska Island, Alaska	bulk carrier with approximately 1,800 m³ of intermediate fuel oil (IFO 380) and 70 m³ of marine diesel oil (MDO) ran aground; broke in two	474 m³ of IFO 380 recovered; remaining 1,326 m³ of IFO 380, all of MDO lost to sea; fishing activities in the immediate vicinity of the wreck suspended; poor weather conditions prevented any response at sea and initial shoreline operations restricted to protective booming of salmon rivers; approximately 2,000 marine birds, 10 sea otters oiled; following spring SCAT surveys determined that 113 km of shoreline required further clean up commanding officer of cargo ship the condemned to three years probation [ITOPF, 2016; State of Alaska, 2005; Cedre, 2005; NTSB, 2006]
MSC ILONA	**2004** Dec 7	Pearl River, Guangdong, China	container ship MSC Ilona was hit by the container ship Hyundai Advance; port side of the MSC Ilona ripped open causing 1283 tonnes of bunker fuel to be released	slick 16 km long by 200 m wide formed at the mouth of Pearl River; clean up by fisherman; 8,000 dead birds and 13,000 oiled birds; cost $6 million US [Cedre, 2014]

Incident	Date	Location	Description	Consequences
ATHOS 1	**2004** Nov 26	Delaware river, Philadelphia, PA	oil tanker approaching a loading terminal hit part of an unindicated metal pipe	approximately 1,000 tonnes of highly viscous crude oil released; more than 200 km of coastline polluted; more than 30 km of booms deployed; two sectors of a nuclear plant temporarily closed; significant environmental and economic damage resulted [NOAA, 2014; Cedre, 2004]
VICUÑA	**2004** Nov 15	Paranaguá, Brazil	chemical tanker suffered two explosions during unloading of the cargo of 14,000 tonnes of methanol; vessel broke in two and spilled approximately 400 tonnes of bunker fuel oil	two crew members killed in the accident and two others reported missing; wreck surrounded with antipollution booms12 hours after the accident; fishing and the sale of aquacultural produce banned in the bay until the contamination risks disappeared; dolphins, turtles and birds affected by the pollution [Cedre, 2004]
BULK CARRIER ROCKNES	**2004** Jan 19	Near Bergen, Norway	specialized bulk carrier laden with a cargo of rock ran into difficulties and capsized; 466 tonnes of Intermediate Fuel Oil (IFO 380) and 78 tonnes of marine diesel as well as lubrication oils on board	18 crew members died; approximately 200 tonnes of IFO 380 spilled, and spread up to 10 NM from the incident site [ITOPF, 2016]
TASMAN SPIRIT	**2003** Jul 27	entrance to Karachi Port, Pakistan	tanker loaded with 67,000 tonnes of Iranian crude grounded at the entrance to Karachi Port, Pakistan	27,000 tonnes of oil spilled; much of the spilled oil quickly stranded on Clifton Beach; some 140 tonnes of oil recovered by skimmers; significant quantities remained afloat both inside and outside Karachi port; local hospitals reported many cases of headaches, nausea and dizziness;17 schools in the vicinity closed for about a week [ITOPF, 2016; Cedre, 2004]
FU SHAN HAI GDYNIA	**2003** May 31	off Bornholm Island, Denmark	bulk carrier Fu Shan Hai collided with the container ship Gdyni; Fu Shan Hai severely damaged, began to sink and leak; carrier towed but eight hours after the collision sank in waters 68 m deep where it continued to leak	cargo of 66,000 tonnes of potash, 1, 800 tonnes of fuel oil and 110 tonnes of diesel oil and lubricants aboard spilled; 1,200 tonnes of oil recovered; at sea and on land; recovery operations cost 89 million Swedish Krona [Cedre, 2009]
SPABUNKER IV	**2003** Jan 21	Port of Algeciras, Andalusia, Spain	vessel caught in a storm; developed leak; sank in waters 50 m deep with 1,000 tonnes of oil onboard (900 tonnes of light fuel oil and 100 tonnes of diesel)	pollution quickly controlled [Cedre, 2009]

Incident	Date	Location	Description	Consequences
PRESTIGE	**2002** 13 Nov	off Cape Finisterre, Galicia, Spain	single hulled tanker carrying 77,000 tonnes heavy fuel oil (n°2, M100); suffered hull damage in heavy seas off northern Spain; towed out to sea; broke in two some 170 miles west of Vigo; sank into 3500 metres of water	estimated 64,000 tonnes spilled; open-sea recovery operation off Spain reportedly removed almost 50,000 tonnes of oil-water mixture; cost of some €100 million to remove the oil remaining in the wreck; 1,140 oiled beaches, 2,900 km of coastline affected in France, Spain and Portugal; between 115,000 and 230,000 dead birds; cost for French victims totalled an estimated €110 million [ITOPF, 2016; Cedre, 2014]
LIMBURG	**2002** Oct 6	3 nautical miles from Ash-Shihr port, Hadramawt province, Yemen	double hull oil tanker hit by explosives from a small craft; starboard tank number 4 holed in two places; spilled hydrocarbon on fire.	12, 000 tonnes spilled; fire lasted for 36 hours [Cedre, 2004]
CO-OP VENTURE	**2002** Jul 25	Shibushi Bay, 1.6 km off Osaki (Japan)	cargo vessel ran aground sustaining a split hull and has been stranded ever since; cargo of corn	958 m^3 bunker fuel spilled; 70% of oil recovered four people died from hydrogen sulphide emanations caused by the corn decomposition [Cedre, 2009]
AVERITY	**2001** Sep 26	Stanlow Dock, entrance to Manchester canal, UK	tanker loading cargo of low sulphur diesel	150 tonnes of diesel spilled because two sea valves left open in the pump room; pollution contained within the dock; FT Everard, the owners of the vessel fined £10,000 (~ € 15,000) [Cedre, 2007]
TERN	**2001** Mar 28	Kadet fairway, Jutland islands, Baltic Sea	cargo vessel Tern collided with the oil tanker Baltic Carrier carrying 30,000 tonnes of heavy fuel oil; starboard side of tanker ripped open	2,700 tonnes of oil spilled; slicks washed up on the shores of the four Danish islands; 3,950 tonnes of polluted waste collected [Cedre, 2014]
JESSICA	**2001** Jan 16	Wreck Bay, Galapagos islands	tanker ran aground during a storm; cargo- 600 tonnes of diesel and 300 tonnes of IFO 120	approximately 600 tonne of oil leaked; slicks started drifting west north west; staff from the US Coast Guard and the National Oceanic and Atmospheric Administration arrived on 21 January with response equipment; 370 large animals affected by oil; effects on subtidal reef communities generally localized within approximately 100 m of the wreck site [Cedre, 2001]

Incident	Date	Location	Description	Consequences
CORAL BULKER	**2000** Dec 25	Port of Viana do Castelo, Portugal	bulk carrier hit the outside harbour wall; bilge severely damaged; starboard side tank n°4 and engine room flooded	630 tonnes of heavy fuel oil, 70 tonnes of diesel oil spilled; shore line polluted; 6,500 bags of fuel and polluted sand collected [Cedre, 2003]
NATUNA SEA	**2000** Oct 3	Island of Batu Berhandi, Singapore Strait	tanker grounded on reef; cargo - 70,000 tonnes of Nile Blend crude oil; several cargo tanks damaged	about 7,000 tonnes spilled; contaminating shorelines in Singapore, Indonesia and Malaysia [ITOPF, 2016; Cedre, 2001]
EUROBULKER IV	**2000** Sep 8	Porto Vesme, Italy	bulk carrier carrying 17,000 tonnes of coal, 35 tonnes of diesel oil and 170 tonnes of bunker fuel ran aground on rocks; hull damaged	60 tonnes of bunker fuel leaked out [Cedre, 2009]
TREASURE	**2000** Jun 14	Robben Island, South Africa	bulk carrier suffered structural damage; tow out to sea; sank near Robben Island	1,000 tonnes of heavy fuel oil released; ecologically sensitive area; penguins moved 800 km away at a cost of 300 € per penguin; estimated total cost of the damage: over 1.5 million Euros International Marine Organization (IMO) created the Southern South Africa Sea Area prohibiting or severely restricting the dumping of oily waste in this area [Cedre, 2007]
ERIKA	**1999** 11Dec	Bay of Biscay	single hulled tanker carrying some 31,000 tonnes of heavy fuel oil (no. 6) broke in two in a severe storm	about 20,000 tonnes spilled; 11,200 tonnes recovered; intermittent oiling occurred over some 400 km of shoreline between Finistère and Charente-Maritime; island of Groix severely affected; bulk of the pollution reached the north and south banks of the Loire River; almost 50,000 birds killed; salt production affected; €179 million paid in compensation [ITOPF, 2016; Cedre, 2012]
SEA EMPRESS	**1996** Feb 15	entrance to Milford Haven, South-West Wales	single hulled tanker carrying 130,824 tonnes of Forties Blend North Sea crude oil ran aground at St Ann's Head	72,000 tonnes of crude oil and 370 tonnes of heavy fuel oil released into sea; 200 km of coastline contaminated; seaweeds and shore invertebrates along the rocky shores, shellfish on sandy beaches and rock pool fishes smothered by oil, more than 2,200 birds killed [ITOPF, 2016; Cedre, 2011]
MV BRAER	**1993** 5 Jan	Garth's Ness, Shetland	tanker ran aground on rocks in Quendale Bay, just west of Sunburgh Head, on the south tip of Shetland; tanker broke into three sections	entire cargo (85,000 tonnes of Norwegian Gullfacks **crude oil** and up to 1,500 tonnes of heavy bunker oil) spilled into the sea; oil heavily contaminated salmon farms causing extensive economic damage; tides spread the oil underwater around the Shetland's 900 miles of coastline; more than1,500 birds killed; total payment amounted to £58.4 million [ITOPF, 2016; Cedre, 1994]

Incident	Date	Location	Description	Consequences
AGEAN SEA	**1992** 3 Dec	La Coruña, Spain	Greek OBO carrier (ore/bulk/oil) carrying 80,000 tonnes of North Sea Brent crude ran aground approaching the port; vessel broke in two; caught fire; burned for several days	smoke caused temporary evacuation of La Coruña 73,000 tonnes, released - either dispersed at sea or consumed by fire; 700 tonnes of bunker fuel, recovered; over 300 km of shoreline contaminated; clean up recovered approx. 5,000 tonnes of oil/water mixture and 1,200 m^3 of contaminated sand and debris; ban on fishing and on sale of all seafood from the area; fishery (mussels and salmon) destroyed; compensation €54 million [ITOPF, 2016; Cedre, 2007]
KATINA P	**1992** 17 Apr	Mozambique Channel	tanker carrying 67,000 tonnes of heavy fuel oil, disabled by a freak wave; two tanks burst open, releasing 13,000 tonnes of crude oil; crew beached the ship on a sand bank in Maputo Bay releasing a further 3,500 tonnes into the Indian Ocean; vessel refloated but broke in two and sank approx. 85 nautical miles off Mozambique, releasing all the remaining oil	total of 67,000 tonnes of heavy fuel oil released oil released; U.S. experts (USCG, NOAA and EPA) helped the Mozambique Government to organize clean up of the shoreline, polluted by some 500 tonnes of oil; spill had major socioeconomic consequences for Mozambique; polluted environment extremely sensitive (bays, mangroves, estuaries, islands and beaches); compensation of $4.5 million [ITOPF, 2016; Cedre, 2012]
ABT SUMMER	**1991** 28 May	900 miles off the coast of Angola	vessel containing 260,000 tonnes of Iranian heavy crude oil exploded and caught fire; burned for three days before sinking	five crew died; large slick covering an area of 80 square miles spread around the tanker and burned fiercely; little environmental impact [ITOPF,2016; Cedre, 2010]
HAVEN	**1991** 11 Apr	Genoa Roads, Italy	VLCC loaded with 144,000 tonnes of Iranian heavy crude oil, caught fire, exploded and broke into three parts; one parts sank on the spot, the others sank during towing	six crew killed; 144,000 tonnes of oil spilled; approx. 5,500m^3 of oil recovered; almost 110 km of coastline, rocks and beaches cleaned up; significant impact on fauna; payments of 95.5 billion Lira made to Italian claimants (fishermen and tourist businesses); 23 million Francs to French claimants [ITOPF, 2016; Cedre, 2011]
AGIP ABRUZZO	**1991** 10 Apr	port of Livorno, Italy	tanker Agip Abruzzo carrying around 80,000 tonnes of Iranian light crude oil collided with ro-ro ferry Moby Prince	142 on ferry killed in explosion and fire which lasted seven days; about 2,000 tonnes of crude oil and an unknown amount of Intermediate Fuel Oil (IFO) 380 bunkers released; about 130 km of the surrounding coastline polluted with oil; compensation of £7.2 million paid to companies involved in clean up by vessel owner [ITOPF,2016; Cedre, 2011]
KHARK 5	**1989** 19 Dec	coast of Safi, 400 miles north of the Canary Islands	explosion; four tanks damaged causing a continuous spill of 70,000 tonnes of Iranian crude oil; over about 12 days, leaks estimated at 200 t/h reported	coast and oyster beds at Oualidia endangered [ITOPF, 2016; Cedre, 2007; NOAA, 1989]

Incident	Date	Location	Description	Consequences
EXXON VALDEZ	**1989** 24 Mar	Prince William Sound, Alaska	supertanker with 180,000 tonnes of crude oil grounded on Bligh Reef; 11 of 18 tanks damaged	38,500 tonnes of Alaska North Slope crude escaped; more than 7,000 km^2 of oil slicks polluted 2000 km of coasts; less than 10% of the original spill volume recovered from the sea surface; more than 36,000 birds and more than 1,000 sea otters died; Exxon Mobil paid $4.3 billion US as a consequence of the spill; this disaster resulted in the "double hull" amendment of 6 March 1992 being promulgated and voted in for all vessels built after 6 July 1996 (MARPOL convention, rule 13F). [ITOPF, 2016; Cedre, 2014]
NESTUCCA	**1988** 23 Dec	near Gray's Harbor, Washington	tug Ocean Service collided with its tow, the barge Nestucca; barge was carrying over 69,000 barrels of Number 6 fuel oil; tug punctured a cargo tank, releasing an estimated 5500 barrels of the heavy marine fuel into the ocean	spill drifted to west coast of Vancouver Island, oiling beaches; approx. 56,000 seabirds killed; BC Ministry of Environment adopted Incident Command System (ICS) [NOAA, 1998; BCE, 1988]
ODSSEY	**1988** 10 Nov	North Atlantic 700 miles off the coast of Nova Scotia	tanker almost fully loaded with a cargo of 132,157 tonnes of North Sea Brent crude oil floundered in heavy weather and exploded; broke into two and sank	27 crew members lost; an oil slick 16 km long by 5 km wide drifted eastwards out to sea and never reached shore [ITOPF, 2016; Cedre, 2012]
NOVA	**1985** 6 Dec	90 nautical miles south-east of Khark Island in the Gulf of Iran	very large crude carrier (VLCC) NOVA, carrying 188,000 tonnes of Iranian Light crude oil, collided with ultra large crude carrier (ULCC) MAGNUM; five cargo tanks damaged	a spill of approx. 70,000 tonnes; oil expected to evaporate and disperse at sea [ITOPF, 2016]
CASTILLO DE BELLVER	**1983** 6 Aug	about 70 miles north-west of Cape Town, South Africa	ship carrying 252,000 tonnes of light crude oil (Murban and Upper Zakum), exploded and went up in flames; blazing ship drifted off shore and broke in two generating a spill of 50 to 60,000 tonnes; stern section - possibly with as much as 100,000 tonnes of oil remaining in its tanks - capsized and sank in deep water, 24 miles off the coast	bow section towed away from the coast and eventually sunk with the use of controlled explosive charges; approx. 50-60,000 tonnes estimated to have spilled into the sea or burned; 1,500 gannets oiled; 'black rain' of airborne oil droplets fell during the first 24 hours of the incident on wheat growing and sheep grazing lands due east of the accident [ITOPF, 2016; Cedre, 2010]
TANIO	**1980** Mar 7	North of Batz island, Finistère, France	tanker with 26,000 tonnes of heavy fuel oil (n° 6) and 900 tonnes of bunker fuel oil split in two in violent storm; approx. 13,500 tonnes of oil spilled	eight crew missing stern section, with about 7,500 tonnes of cargo oil aboard, remained afloat and was towed to Le Havre; the bow section, with 5,000 tonnes of oil, sank to a depth of 90 metres; oil drifted to shore contaminating about 200 km of coastline to varying degrees; approximately 1,700 dead birds [ITOPF, 2016; Cedre, 2003]

Incident	Date	Location	Description	Consequences
IRENES SERENADE	**1980** 23 Feb	Navarino Bay, Greece	tanker with cargo of 102,660 tonnes of Iraqi crude oil (Kirkuk Blend) at anchor at the bunkering location suffered explosions in the forecastle which set the cargo alight	oil slick two miles long by half a mile wide spread from the vessel; both the tanker and the surrounding water burned for 14 hours until the following morning when the tanker sank off Pylos Harbour, close to Sfakteria Island [ITOPF, 2016]
INDEPENDENTA	**1979** 15 Nov	Haydarpasa at entrance to the Bosphorus, in Turkey	tanker with 93,800 tonnes of Libyan Es Sider crude oil collided with the Greek cargo ship EVRIALI; tanker broke in two and its stern section sank; cargo of oil escaped, some of which fed the fire while the rest drifted in the form of ignited slicks	42 crew members died in the ensuing explosion and fire on board the tanker and from burning oil on the water; buildings reportedly damaged up to six km away; estimated 50 tonnes of oil reached the port of Haydrapasa; Bosphorus closed for traffic for a number of weeks [ITOPF, 2016; Cedre, 2012]
ATLANTIC EMPRESS	**1979** 19 Jul	10 miles off Tobago	two fully loaded VLCCs, Atlantic Empress (carrying 276,000 tonnes of crude oil) and the Aegean Captain (carrying 200,000 tonnes of crude oil) collided; Atlantic Empress and the bow part of the Aegean Captain went up in flames; blazing ATLANTIC EMPRESS towed further out to sea; 300 nautical miles offshore, a large explosion caused severe damage to the vessel; it began to list and sank on 2 Aug	26 sailors killed; estimated 287,000 tonnes of oil spilled; no significant shore pollution was recorded on the nearest island [ITOPF, 2016; Cedre, 2007]
KURDISTAN	**1979** 15-16 Mar	Cabot Strait 93 km north-east of Sydney, Nova Scotia	tanker carrying 30,000 tonnes of fuel oil (Bunker C) broke in two; 7,000 tons of bunker C released; damage was attributed to a fracture initiated by a weld defect and aggravated by wave impacts on the bow at low temperatures	bow which remained afloat with its 7,000 tonnes of fuel oil towed to sea and scuttled in 2,000 fathoms 200 nautical miles off Nova Scotia; stern section towed to harbor;16,000 tonnes of oil off-loaded; oil drifted ashore in Cape Breton; 880 km of shoreline cleaned up; a hundred fish nets laundered; between 12,000 and 25,000 birds killed; seals impacted [Cedre, 2010; NOAA, 1979]
BETELGEUSE	**1979** 8 Jan	terminal on Whiddy Island in Bantry Bay, Ireland	oil tanker unloading cargo, composed of 74,000 tonnes of Arabian heavy crude oil and 40,000 tonnes of Arabian light crude oil; 40,000 tonnes of light still onboard when the vessel exploded	42 crew members of the *Betelgeuse* and seven workers from the oil terminal died in the explosion; ship split in two in the explosion; both parts sank; 40,000 tonnes of Arabian light crude oil spilled; explosion also set the vessel on fire; jetty and terminal seriously damaged; pollution affected the fishing industry; total claims $120 million US [Cedre, 2004]
AMOCO CADIZ	**1978** 16 Mar	Portsail, North Finistere (off the coast of Brittany)	tanker ran aground; over a period of two weeks entire cargo (223,000 tonnes of light Iranian and Arabian crude oil and 4,000 tonnes of bunker fuel) released into heavy seas	oil and emulsion polluting 360 km of shoreline from Brest to Saint Brieuc; nearly 20,000 dead birds recovered; oyster cultivation affected; Amoco paid 190 million euros damages [ITOPF, 2016; Cedre, 2008]

Incident	Date	Location	Description	Consequences
HAWAIIAN PATRIOT	**1977** 23 Feb	300 miles west of Hawaii	ship transporting 99,000 tonnes of light Indonesian crude oil; hull plating cracked during a storm; approx., 18,000 tonnes of oil leaked into the sea; on the following day the tanker caught fire and exploded; burned fiercely for several hours and sank with the remaining cargo on board	one crew member died; resultant oil slick, estimated to contain about 50,000 tonnes of oil, carried westward away from Hawaii by ocean currents and did not result in pollution problems on land [ITOPF, 2016; Cedre, 1212]
URQUIOLA	**1976** 12 May	La Coruña, Spain	struck bottom on entering the port; began leaking oil; struck bottom again on its way out of port and ran hard aground between the two entrance channels with its bow resting in approximately 30 m of water; vessel exploded	one killed; estimated 100,000 tonnes of Arabian Light crude oil spilled and burned for 16 hours; black smoke spread out over the city of La Coruña; oil spread rapidly throughout port and towards surrounding coastline; an estimated 25-30,000 tonnes washed ashore; flora and fauna took several years to recover; response expenses and economic losses estimated at 70 million Euros. [ITOPF, 2016; Cedre, 2011]
JAKOB MAERSK	**1975** 29 Jan	entrance to port of Leixoes, northern Portugal	ship with cargo of about 88,000 tonnes of oil (Iranian light crude oil, bunker fuel oil) hit sandbank; explosion and fire resulted; broke into three parts	seven crew members killed; explosions and a fire spread to cargo holds and to oil floating on the water; 40,000 -50,000 tonnes of oil consumed by fire; 25,000 tonnes estimated to have drifted out to sea; 15,000 tonnes contaminated shore; sky above Porto darkened by a thick black smoke for several days; several inhabitants hospitalized by smoke; heaviest contamination found in a 3-4 km stretch immediately adjacent to vessel; cost estimated at $2.8 million US [ITOPF, 2016; NOAA, 1975; Cedre, 2003]
METULA	**1974** 9 Aug	eastern Strait of Magellan, Chile	ship grounded	47,000 tonnes of light Arabian crude oil and 3,000 - 4,000 tonnes of heavy fuel oil estimated lost about 4,000 birds killed [ITOPF, 2016]
SEA STAR	**1972** 19 Dec	Gulf of Oman	SEA STAR collided with tanker HORTA BARBOSA and exploded; both vessels caught fire; fire on HORTA BARBOSA extinguished within a day; SEA STAR continued to burn; after a series of explosions, SEA STAR sank five days later	12 crew members on SEA STAR killed; approximately 115,000 tonnes of crude oil spilled [ITOPF, 2016; Cedre, 2012]

Incident	Date	Location	Description	Consequences
ARROW	**1970** 4 Feb	Chedabucto, Nova Scotia	tanker encountered severe weather and ran aground on Cerberus Rock, split in two with the stern sinking in deeper water; attempts to take off the cargo not successful; stern not recovered	10,330 tons of fuel spilled, coating 75 miles of the shoreline with thick black sludge; only 10% subjected to cleanup, the rest left to degrade naturally; in 1997 much oil remained in the sediment (426–12,744 ppm) but habitat recovery was evident; remaining oil removed from wreck in Oct 2015; resulted in major amendments to Canada Shipping Act regarding liability and compensation [NSM, 2007; RC, 1971, CBC, 2015]]
TORREY CANYON	**1967** 18 Mar	near Lands End, Cornwall	ran aground on Pollard Rock on the Seven Stones Reef; approx. 119,000 tonnes of Kuwait crude oil lost into sea or burned	more than15,000 seabirds died; many of the detrimental impacts of the spill later related to the high volume, high concentration & high toxicity of the dispersant and detergents used; initiated first elements of the French, British & European policies of prevention and response against great oil slick disasters. [ITOPF, 2016; NOAA,1967]

Note: data on marine spills primarily from:

- The International Tanker Owners Pollution Federation Limited (ITOPF) Case Studies [http://www.itopf.com/in-action/case-studies/]
- Centre of Documentation, Research and Experimentation on Accidental Water Pollution (CEDRE) Alphabetical Classification [http://wwz.cedre.fr/en/Our-resources/Spills]
- Canadian Oil Spill Incidents are detailed in the Ship Source Oil Pollution Fund [http://www.ssopfund.ca/incidents]
- NOAA Incident News [https://incidentnews.noaa.gov/browse/date?page=1]

These references have detailed information on the incident including additional reference and photographs.

The ITOPF report Oil Tanker Spill Statistics 2015 [http://www.itopf.com/fileadmin/data/Documents/Company_Lit/Oil_Spill_Stats_2016.pdf] has data on current trends.

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NOAA Incident News (1975) Jakob Maersk, Leixoes, Portugal 1975-Jan-29 [https://incidentnews.noaa.gov/incident/6221]

NOAA Incident News (1988) T/B NESTUCCA, Grays Harbor, Washington, 1988-Dec-23 [https://incidentnews.noaa.gov/incident/6641

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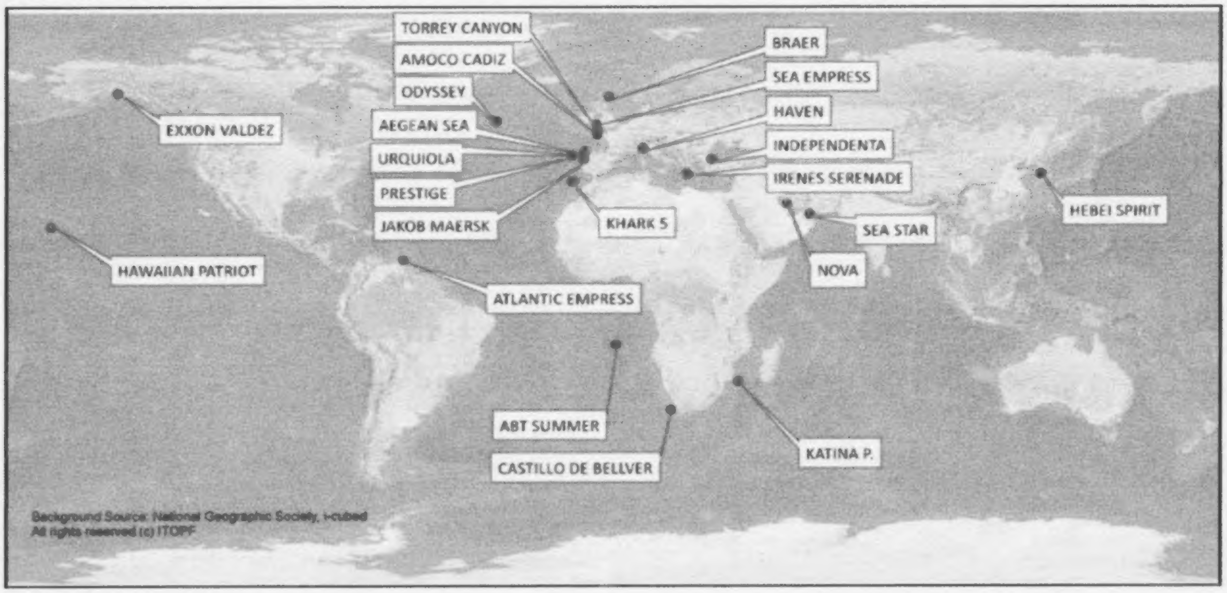
Location of Top 20 Major Oil Spills (based on volume spilled)

The top 20 major oil spills that have occurred since the TORREY CANYON in 1967 are shown below; it is of note that 19 of the largest spills recorded occurred before the year 2000. A number of these incidents, despite their large size, caused little or no environmental damage as the oil was spilled some distance offshore and did not impact coastlines. It is for this reason that some of the names listed may be unfamiliar. EXXON VALDEZ and HEBEI SPIRIT are included for comparison although these incidents fall some way outside the group in terms of volume spilled.


TORREY CANYON
AMOCO CADIZ
ODYSSEY
AEGEAN SEA
URQUIOLA
PRESTIGE
JAKOB MAERSK
EXXON VALDEZ
HAWAIIAN PATRIOT
BRAER
SEA EMPRESS
HAVEN
INDEPENDENTA
IRENES SERENADE
KHARK 5
SEA STAR
NOVA
HEBEI SPIRIT
ATLANTIC EMPRESS
ABT SUMMER
CASTILLO DE BELLVER
KATINA P.

Background Source: National Geographic Society, i-cubed
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Top 20 Major Spills Table

Position	Ship Name	Year	Location	Spill Size (tonnes)
1	ATLANTIC EMPRESS	1979	Off Tobago, West Indies	287,000
2	ABT SUMMER	1991	700 nautical miles off Angola	260,000
3	CASTILLO DE BELLVER	1983	Off Saldanha Bay, South Africa	252,000
4	AMOCO CADIZ	1978	Off Brittany, France	223,000
5	HAVEN	1991	Genoa, Italy	144,000
6	ODYSSEY	1988	700 nautical miles off Nova Scotia, Canada	132,000
7	TORREY CANYON	1967	Scilly Isles, UK	119,000
8	SEA STAR	1972	Gulf of Oman	115,000
9	IRENES SERENADE	1980	Navarino Bay, Greece	100,000
10	URQUIOLA	1976	La Coruna, Spain	100,000
11	HAWAIIAN PATRIOT	1977	300 nautical miles off Honolulu	95,000
12	INDEPENDENTA	1979	Bosphorus, Turkey	94,000
13	JAKOB MAERSK	1975	Oporto, Portugal	88,000
14	BRAER	1993	Shetland Islands, UK	85,000
15	AEGEAN SEA	1992	La Coruna, Spain	74,000
16	SEA EMPRESS	1996	Milford Haven, UK	72000
17	KHARK 5	1989	120 nautical miles off Atlantic coast of Morocco	70,000
18	NOVA	1985	Off Kharg Island, Gulf of Iran	70,000
19	KATINA P	1992	Off Maputo, Mozambique	67,000
20	PRESTIGE	2002	Off Galicia, Spain	63,000
35	EXXON VALDEZ	1989	Prince William Sound, Alaska, USA	37,000
131	HEBEI SPIRIT	2007	South Korea	11,000

Annex L: List of Major Crude Oil Spills Involving Drilling Platforms

Incident	Date	Location	Description	Consequences
Deep Water Horizon (Macondo blowout)	**2010** 20 Apr	Gulf of Mexico 80 km off the coast of Louisiana	Fire and explosion on the DEEPWATER HORIZON, a semisub-mersible drilling platform; rig sinks; sea-floor oil gusher flowed for 87 days, until capped on 15 Jul 2010 and sealed on 19 Sep 2010	• 11 dead; 17 injured; estimated total discharge at 4.9 million barrels; 2,500 to 68,000 sq mi affected; total cost of $61.6 Bn (Jul 2016); litigation ongoing [National Commission, 2011; Mufson, 2016]
West Atlas (Montara)	**2009** 21 Aug	Montara offshore oil field, Timor Sea, Australia	Uncontrolled discharge of oil and gas (light crude oil and mixture of condensates and gas), 64 tons per day (400 barrels) of crude oil lost each day until 3 Nov 2009; well capped on 3 Dec 2009 (105 days)	• 4,800 tonnes spilled; slick created stretched up to 40 km wide by 136 km long; 844 m^3 of emulsion recovered, 58% (493 m^3) crude oil; oil did not impact on sensitive marine resources • [Cedre, 2009; AMSA, 2010a; AMSA 2010b]
Statfjord A	**2007** 2 Dec	Statfjord A offshore oil platform, some 200 km west of Bergen, Norway	4,000 m^3 of crude oil spilled into the North Sea	• slick around 10 km long and 5 km wide, with an average thickness of less than 100 microns; left to natural dispersion [Cedre, 2011a]
Perforadora Central Usumacinta	**2007** 23 Oct	**Gulf of Mexico** coast of Tabasco, near the port of Dos Bocas	23 Oct 2007: collision of the cantilever deck of the Usumacinta and the top of the production valve tree of the Kab-101 platform, causing a leak in oil and gas; 13 Nov, a spark from ongoing containment work caused a significant fire to ignite on the Usumacinta extinguished on14 Nov; 20 Nov, second fire causing immense damage to the Usumacinta platform including the collapse of its derrick and severe damage to the cantilever deck and connecting bridge.	• 22 dead (difficulty with lifeboat) • initially spill estimated to leak 442 barrels of light crude a day, approx. 40% of this spillage evaporated; a total of 8701 barrels recovered; estimated 5000 barrels lost; over 500 tons of sand with hydrocarbons (estimated to be equivalent to 394 barrels of oil) recovered from shore • [Offshore Technology, 2010; Hanlon, 2013]

Incident	Date	Location	Description	Consequences
Nowruz oil field	**1983**	Iranian Nowruz oil field, Persian Gulf Note: war zone Iran-Iraq War	10 Feb, 1983, a tanker collided with a platform (well no. 3) which developed a 45-degree tilt necessitating shut down; wave action and corrosion apparently caused the riser to collapse into the wellhead causing a spill of approx. 1,500 barrels per day; platform attacked by Iraqi planes in March; resulting slick caught fire; well capped on 18 Sep1983. Mar1983, a nearby platform (well no. 4) attacked with rockets by Iraqi helicopters; burned and spilled oil at a rate of approx. 5,000 barrels per day; rate slowed to about 1,500 barrels per day in the two years before the well was capped; May 1985, the fire extinguished and the well plugged.	• 11 killed in 1983 in well no. 3 incident • 9 killed in well no. 4 incident; approx. 733,000 barrels of oil spilled into the sea • estimated that the rate of oil leaking into the Persian Gulf in mid-May of 1983 between 4,000 and 10,000 barrels per day due to more war-related activity or the collapse of burning platform • total quantity of oil spilled in the Persian Gulf 1983 – 1985 estimated at 260,000 tonnes • [Cedre, 2010; NOAA, 1985]
Hasbah 6	**1980** Oct 2	250 km NW of Qata	Exploratory well No. 6, drilled by the rig Ron Tappmeyer in the Hasbah oil field, blew out; hazard caused by the release of hydrogen sulfide gas delayed efforts to control the blowout.	• well discharged oil until 10 Oct when it was capped; 100,000 barrels released • 19 killed [NOAA, 1980a; Offshore Technology, 2010]
Funiwa No. 5	**1980** 17 Jan	5 miles off the Niger Delta, Nigeria	Funiwa No. 5 well blew out; fire started 29 Jan; flow stopped 1 Feb	• 230 people died as a result of pollution • approx 200,000 barrels spilled; mangrove forests polluted with about 836 acres destroyed • [NOAA, 1980b; Offshore Technology, 2010]
IXTOC I (Sedco 135F)	**1979** 3 Jun	Gulf of Mexico Bahia de Campeche, 600 miles south of Texas in the Gulf of Mexico	Two mile deep exploratory well, IXTOC I, destroyed by the blast of an oil eruption; oil and gas blowing out of the well ignited, causing the platform to catch fire; burning platform collapsed into the wellhead area hindering any immediate attempts to control the blowout; eruption only stopped on 23 Mar 1980, after 295 days, during the which the oil spurt had been reduced first from 4,200 – 4,300 tonnes/day to 1,400 – 1,500 tonnes/day cause: loss of drilling mud circulation	• estimated 470,000 tonnes spilled; between half and a third of this oil burned, causing vast atmospheric pollution; remaining part spread over the Gulf of Mexico in the form of drifting slicks measuring 180 km by 80 km; extensive damage along the U.S. coast, especially in Texas; shrimp nurseries, mangroves, beaches and seabirds oiled; fishing and tourist activities affected; estimated total cost $1.5 billion US • [Cedre, 2000; NOAA, 1979; Jernelöv, 1981]

Incident	Date	Location	Description	Consequences
Ekofisk B	**1977** 22 -30 Apr	Ekofisk Field, Norwegian Continental Shelf, about 300 km south-west of the Ekofisk oil field centre	Oil and natural gas blowout occurred in well B-14 of the Phillips Petroleum Company's Bravo production platform; mixture of oil and mud spurted up to 50 m into the air above the offshore drilling rig; blowout resulted in the continuous release of about 30,000 tonnes of oil from a pipe 20 metres above the sea surface until the leak was finally stopped seven days later on 30 April cause: "blowout preventer" apparently been placed upside down on the wellhead during an earlier maintenance procedure	• calculated total release of 32, 200 tonnes; large part of the oil (30 - 40 %) rapidly evaporated due to higher than average air temperatures; remaining oil slicks gradually broken down by wave action; no shorelines oiled; no major ecological damage resulted [Cedre, 2011b; NOAA, 1977]
Santa Barbara	**1969** 28 Jan	5.5 miles southeast of Santa Barbara, California, in the Dos Cuadras field	Union Oil Company well number 21 under Platform A experienced a blowout while drill bits were being changed; massive mixture of oil, gas, and drilling mud roared up the drill casing and spewed out onto the platform; capped on 7Feb; oil continued to vent from natural faults several hundred yards from the platform, in tract 4042 between the coast and a chain of islands; faults released a total of 100,000 barrels of oil until Dec 1969	• beaches of Santa Barbara County fouled from Goleta to Ventura as well as the northern shores of four northern Channel Islands; slick covered 75 sq mi; killed approx. 3500 birds, affected marine mammals; economic effects extensive due to loss of fishing income, loss of recreational facilities damage to personal property • US Government put environmental legislation in place to protect against such disasters shaping the future for the legislative environment for offshore oil and gas in the U.S. • [NOAA, 1969, NOAA, 1992]

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Annex M: Changes in regulations involving the transportation of crude oil in Canada and the United States resulting from the Lac-Mégantic derailment (not exhaustive)

Date	Issuer	Requirement/Regulation
2013 Jul 18	Transportation Safety Board (TSB) Emergency Directive (ED) 9/13 [TC, 2013]	• requiring a minimum two crew for all trains transporting one loaded tank car or more of dangerous goods. • requiring that no locomotive attached to one loaded tank car or more of dangerous goods be left attended on the main track. • detailing the application of hand brakes and other safety provisions.
2013 Aug 02	U.S. Dept of Transportation (DOT) Federal Railroad Administration (FRA) Safety Advisory (SA) 2013-06, Emergency Order 28 [FR, 2013a]	• no train or vehicle transporting hazardous material shall be left unattended on a mainline track or mainline siding outside of a yard or terminal until the railroad provides a plan to FRA that contains sufficient safety justification for any determination allowing such trains or vehicles to be unattended • development of processes for the securement of unattended trains or vehicles transporting hazardous goods – securing the controlling locomotive cab – requiring the employees responsible for securing trains to communicate to the train dispatcher information on the number of hand brakes applied, the tonnage and length of the train, the grade and terrain features of the track, any relevant weather conditions and the type of equipment being secured; dispatcher must verify that securement meets railroad's requirements • review existing procedures on the number of hand brakes to be set on unattended trains • ensure that a qualified railroad employee inspect all equipment that any emergency responder has been on for proper securement before the train is left unattended
2013 Sep 11	TSB Rail Safety Advisory Letter 12/13 [TSB, 2013]	• requesting review of the processes for suppliers and companies transporting or importing dangerous goods to ensure the properties of the goods are accurately determined and documented for safe transportation.
2013 Oct 17	Transport Canada (TC) Protective Direction (PD) 31 (cancelled) [Noel, 2014]	• directing any person engaged in importing or offering crude oil for transport to immediately test the classification of crude oil being imported, handled, offered for transport or transported as UN 1267 or UN 1993, if the classification testing has not been conducted since July 7, 2013 and to provide those test results to Transport Canada on request • requiring crude oil classified as UN 1267 or UN 1993 by rail be shipped as Class 3 Flammable Liquid Packing Group (PG) 1 until further testing is completed

Date	Issuer	Requirement/Regulation
2013 Nov 14	Association of American Railroads (AAR) [AAR, 2013]	• requesting the US Pipeline and Hazardous Materials Safety Administration (PHMSA) to require even higher standards for DOT-III non-pressure tank cars built to transport flammable liquids and to retrofit all existing cars to this higher standard or phased them out of flammable service – tank cars be equipped with jackets and thermal protection – tank cars must have FULL head shields – high flow capacity safety relief valves (minimum 27,000 scfm) be installed – bottom outlet valve handles be configured to prevent the bottom outlet valves from being opened in an accident – possible design of a new tank car
2013 Nov 20	TC PD 32 (replaced by PD 36) [Noel, 2014]	• requiring that any Canadian Class 1 railway company that transports dangerous goods to provide the designated Emergency Planning Official of each municipality through which dangerous goods are transported by rail, with yearly (by quarter) aggregate information on the nature and volume of dangerous goods the company transports by railway vehicle through the municipality.
2013 Nov 20	PHMSA & FRA Safety Advisory 2013-07 [FR, 2013b]	• emphasizing the importance of proper characterization, classification, and selection of a packing group for Class 3 materials (flammable liquids, including petroleum crude oil), • reinforcing the need to follow the Federal hazardous materials regulations for safety and security planning
2014 Jan 02	PHMSA Safety Alert [PHMSA, 2014]	• warning of crude oil variability and emphasizing that unprocessed crude oil may affect the integrity of packaging or present additional hazards related to corrosivity, sulfur content and dissolved gas content • noting that crude oil being transported from the Bakken region of North Dakota may be more flammable than traditional heavy crude oil
2014 Jan 11	Canada Gazette [GC News, 2014]	• requiring immediate phase-out of DOT-111 tank cars that are not equipped with continuous bottom reinforcement • requiring that all DOT-111 tank cars built before the January 2014 proposed standard that are used to transport crude oil and ethanol be phased out or refitted within three years • detailing proposed new standards for DOT-111tank cars transporting dangerous goods – top-fitting protection – thicker steel for jacketed and non-jacketed cars – half head shields – heads and shells made of normalized steel

Date	Issuer	Requirement/Regulation
2014 Jan 23	TSB [TSB, 2014a; TSB, 2014b]	• requiring all Class 111 tank cars used to transport flammable liquids meet enhanced protection standards that significantly reduce the risk of product loss when these cars are involved in accidents (R14-01) • setting stringent criteria for the operation of trains carrying dangerous goods, and require railway companies to conduct route planning and analysis as well as perform periodic risk assessments to ensure that risk control measures work (R14-02) • requiring emergency response assistance plans for the transportation of large volumes of liquid hydrocarbons, like oil (R14-03).
2014 Feb 25	U.S. Secretary of Transportation Emergency Order (EO) [DOT, 2014a]	• requiring all railroad carriers that transport in a single train in commerce within the United States, 1,000,000 gallons or more of UN 1267, Petroleum crude oil, Class 3,[1] sourced from the Bakken shale, to provide the State Emergency Response Commission (SERC) notification regarding the expected movement of such trains through the counties in the state with information regarding the estimated volumes and frequencies of train traffic implicated (a) provide a reasonable estimate of the number of trains implicated by this Order that are expected to travel, per week, through each county within the state (b) identify and describe the petroleum crude oil expected to be transported in accordance with 49 CFR part 172, subpart C (c) provide all applicable emergency response information required by 49 CFR part 172, subpart G, and (d) identifying the routes over which the material will be transported. • requiring identification of at least one person responsible for serving as the point of contact for SERCs at the railroad (including name, title, phone number and address)
2014 Apr 23	TC PD 33 [Noel, 2014]	• requiring that persons offering for transport or import dangerous goods (e.g., ethanol, crude oil) by rail, in a tank car, if one or more of the rail tank cars in a train are each filled to 10 percent or more of its capacity, have an Emergency Response Assistance Plan (ERAP) • directing every person who offers for transport or imports dangerous goods by rail to have an Emergency Response Assistance Plan (ERAP) approved as set out in section 7 of the *Transportation of Dangerous Goods Act* for: UN1170 ethanol, UN1202 diesel fuel, UN1203 gasoline, UN1267 petroleum crude oil, UN1268 petroleum distillates, n.o.s., UN1863 fuel, aviation, turbine engine, UN1993 flammable liquid, n.o.s., UN3295 hydrocarbons, liquid, n.o.s. or UN3475 ethanol and gasoline mixture.

Date	Issuer	Requirement/Regulation
2014 Apr 23	TC PD 34 [Noel, 2014; TC, 2016a]	• every tank car owner, as defined in CGSB 43.147-2005 must immediately identify each of its tank cars that meet the following criteria: – tank car is of stub sill design and of a CTC 111, DOT 111 or AAR 211 specification; – tank car shell is made of non-normalized ASTM A515 Grade 70 steel plates; – bottom shell of the tank car does not have exterior heater coils; and – bottom shell of the tank car is not continuously reinforced between the end of one of the stub sill's reinforcing plate (stub sill cradle pad) to the end of the other stub sill's reinforcing plate by reinforcing steel bars, steel plate or other structural shapes or by other structural elements such as a bottom discontinuity protection device. • a tank car owner must ensure that every tank car it identifies above is marked with the words "Do not load with dangerous goods in Canada/Ne pas charger de marchandises dangereuses au Canada" or similar words to that effect. • these 5,000 least crash-resistant DOT-111 tank cars be immediately removed from transporting dangerous goods.
2014 May 07	U.S. DOT EO [DOT, 2014b]	• requiring that each railroad carrier to provide the State Emergency Response Commission (SERC) for each state in which it operates trains transporting 1,000,000 gallons or more of Bakken crude oil, notification regarding the expected movement of such trains
2014 May 07	PHMSA and FRA [DOT, 2014c]	• requesting companies to take all possible steps to avoid the use of DOT 111 tank cars when transporting Bakken crude oil
2014 Jul 02	TC [TC, 2014a]	• adopted the Technical Standard Containers for the Transport of Dangerous Goods by Rail (TP14877 which establishes the current minimum safety threshold for TC/DOT-111 tank cars in dangerous goods service in Canada)
2014 Jul 23	U.S. DOT [DOT, 2014d]	• issued a report summarizing the analysis of Bakken crude oil data
2014 Aug 19	TSB [TSB, 2014c]	• report on Lac-Mégantic derailment issued
2015 Feb 24	TC [TC, 2015a]	• requiring companies transporting 1.5 million tones or more of crude oil per year in rail cars to have a minimum of $1 billion in liability insurance coverage. • creating a supplementary shipper-financed fund ($1.65 per tonne of crude oil shipped) to be used in the event of a railway accident involving crude oil

Date	Issuer	Requirement/Regulation
2015 May 08	DOT [DOT, 2015c]	• publication of Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains
2015 May 20	Canada Gazette [CG, 2015]	• regulations Amending the Transportation of Dangerous Goods Regulations (TC117 Tank Cars); additional requirements for tank cars used for crude oil, ethanol, gasoline, diesel fuel, aviation fuel and other flammable liquids
2015 Jul 09	DOE [DOE, 2015]	• release of a Crude Oil Characteristics Research Sampling, Analysis and Experiment (SAE) Plan, which contains recommendations on research needed to improve understanding of transport-critical crude oil and especially tight crude oil properties
2015 Jul 22	DOT [DOT, 2015a]	• instructing railroads transporting crude oil to continue to notify State Emergency Response Commissions (SERCs) and Tribal Emergency Response Commissions (TERCs) of the expected movement of Bakken crude oil trains through individual states and tribal regions - trains with 1,000,000 gallons or more of Bakken crude oil (approximately 35 tank cars) are subject to the notification.
2015 Jul 29	TC [TC, 2015b; TC, 2016d]	• approved revisions to Rule 112 of the Canadian Railway Operating Rules, establishing multiple layers of defence to secure trains and further reduce the risk of runaways is effective on October 14, 2015 • provide industry with a comprehensive handbrake application chart to respond to various operating situations, which once applied, must be confirmed by another employee with the appropriate level of knowledge. • "Railway equipment must be secured by additional physical measures listed in the rules. • "Rules had previously been amended to require the locomotive cabin to be locked and immobilized whenever a train is left unattended to prevent unauthorized entry.
2015 Aug 17	TC ED (revised 19 Feb 2016) [TC, 2016b]	Emergency Directive and Rules Respecting Key Trains and Key Routes • Speed restrictions 40 mph through urban areas and 50 mph otherwise • restrict Key Trains transporting one or more DOT-111 loaded tank cars containing UN1170 ethanol, UN1202 diesel fuel, UN1203 gasoline, UN1267 petroleum crude oil, UN1268 petroleum distillates, n.o.s., UN1863 fuel, aviation, turbine engine, UN1993 flammable liquid, n.o.s., UN3295 hydrocarbons, liquid, n.o.s., UN1987 alcohols n.o.s., UN3494 petroleum sour crude oil, flammable, toxic or UN3475 ethanol and gasoline mixture to a maximum speed of 40 MPH in areas identified as higher risk through the risk assessment process as required under item 6 of this Rule. The DOT-111 tank cars include those that are CPC-1232 specification.
2015 Sep 28	DOT [DOT, 2015b]	• provides $5.9 Million in First Responder Grants to Help Protect Communities From Flammable Liquids by Rail Incidents

Date	Issuer	Requirement/Regulation
2015 Dec 04	PHMSA [PHMSA, 2015]	• signing of Fixing America's Surface Transportation Act, or "FAST Act." Improving PHMSA's ability to oversee the safe and efficient transportation of hazardous materials • Improving the Effectiveness of the Hazardous Materials Grant Programs; • Improving Emergency Preparedness and Response; and • Improving the Safe Transportation of Flammable Liquids by Rail.
2016 Apr 28	TC PD 36 [TC, 2016c]	• Canadian Class I Rail Carrier that transports dangerous goods must, by March 15 of each year, provide the designated Emergency Planning Official of each Jurisdiction through which the Canadian Class I Rail Carrier transports dangerous goods by railway car with a yearly report
2016 Jun 06	TC PD 37 [TC, 2016c]	• requiring top-fitting protection in retrofitted TC/DOT-111 tank cars in Canada
2016 Jul 13	TC PD 38 [TC, 2016c]	• accelerates the phase-out of both jacketed and unjacketed legacy DOT-111 tank cars from being used for crude oil service in Canada as of November 1, 2016
2016 Dec 23	TC MO 16-07 [TC, 2016 d]	• use of rollaway protection on locomotive models GP20 and GP30
2017 Nov 21	TC 2017	• Increase in the levy for the fiscal year starting April 1, 2017, the inflation-adjusted amount is $1.69 per tonne.

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Note: additional United States regulations are available at https://www.phmsa.dot.gov/hazmat/osd/chronology